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(54) **ARTICLE LOCATING AND TRACKING SYSTEM**

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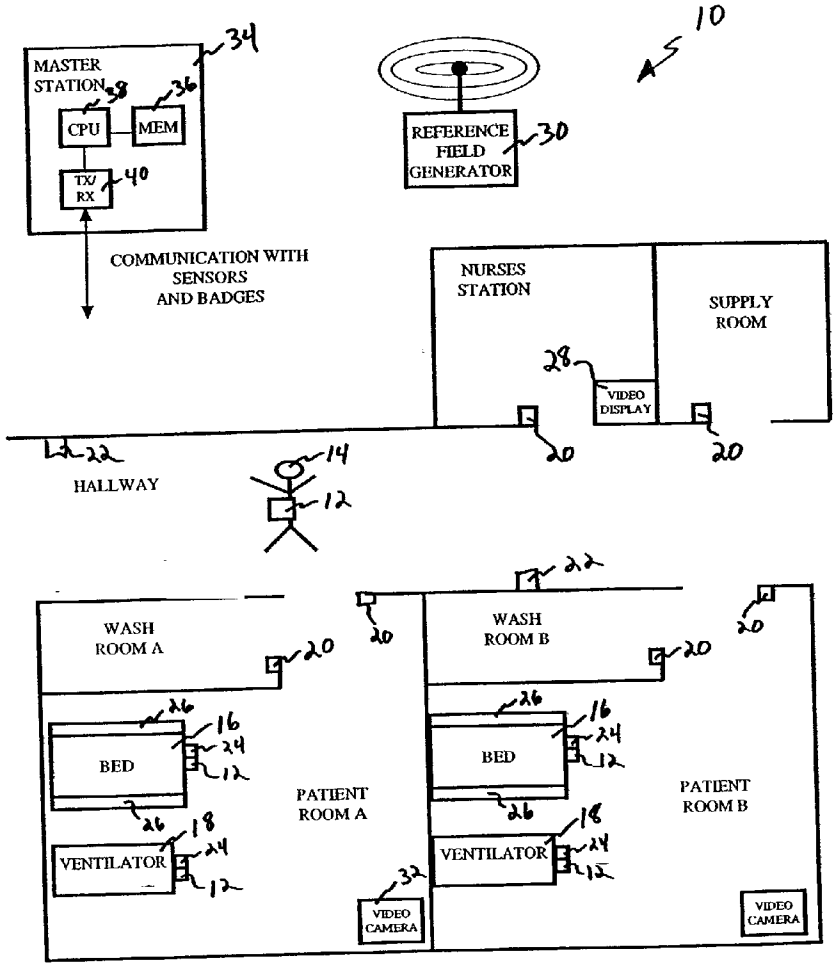
(57) **ABSTRACT**

A system for tracking an activity in a healthcare environment includes a master station having a processor, a memory, and a transceiver, badges coupled to objects, each transmitting a unique badge ID, and sensors disposed throughout the environment, each including a transceiver for receiving badge IDs and transmitting to the master station transceiver the badge IDs and a unique sensor ID that relates the sensor to a location. The master station processor determines object locations from the badge and sensor IDs by identifying the badge associated with the object, relating the sensor ID to the sensor location, and storing object location information in memory. Each badge also includes a displacement sensor that generates signals indicating object movement and direction for transmission to the sensor transceivers which forward displacement information to the master station. The master station processor uses the information to update the stored object location information.



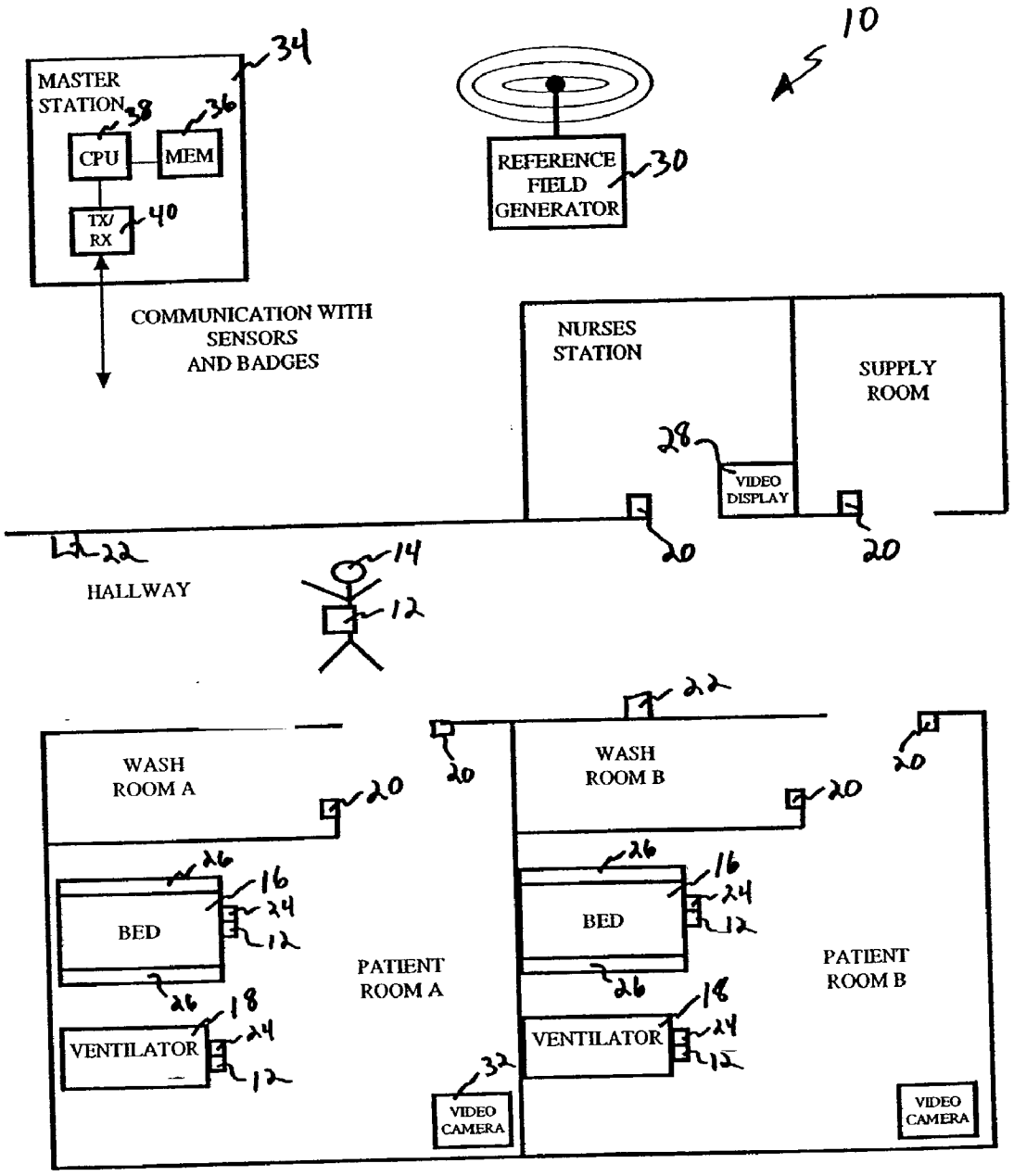

10
MASTER STATION
34
CPU
38
MEM
36
TX/ RX
40
COMMUNICATION WITH SENSORS AND BADGES
REFERENCE FIELD GENERATOR
30
NURSES STATION
SUPPLY ROOM
28
VIDEO DISPLAY
20
22
HALLWAY
14
12
WASH ROOM A
WASH ROOM B
BED
16
24
26
18
VENTILATOR
PATIENT ROOM A
PATIENT ROOM B
32
VIDEO CAMERA

FIG. 1

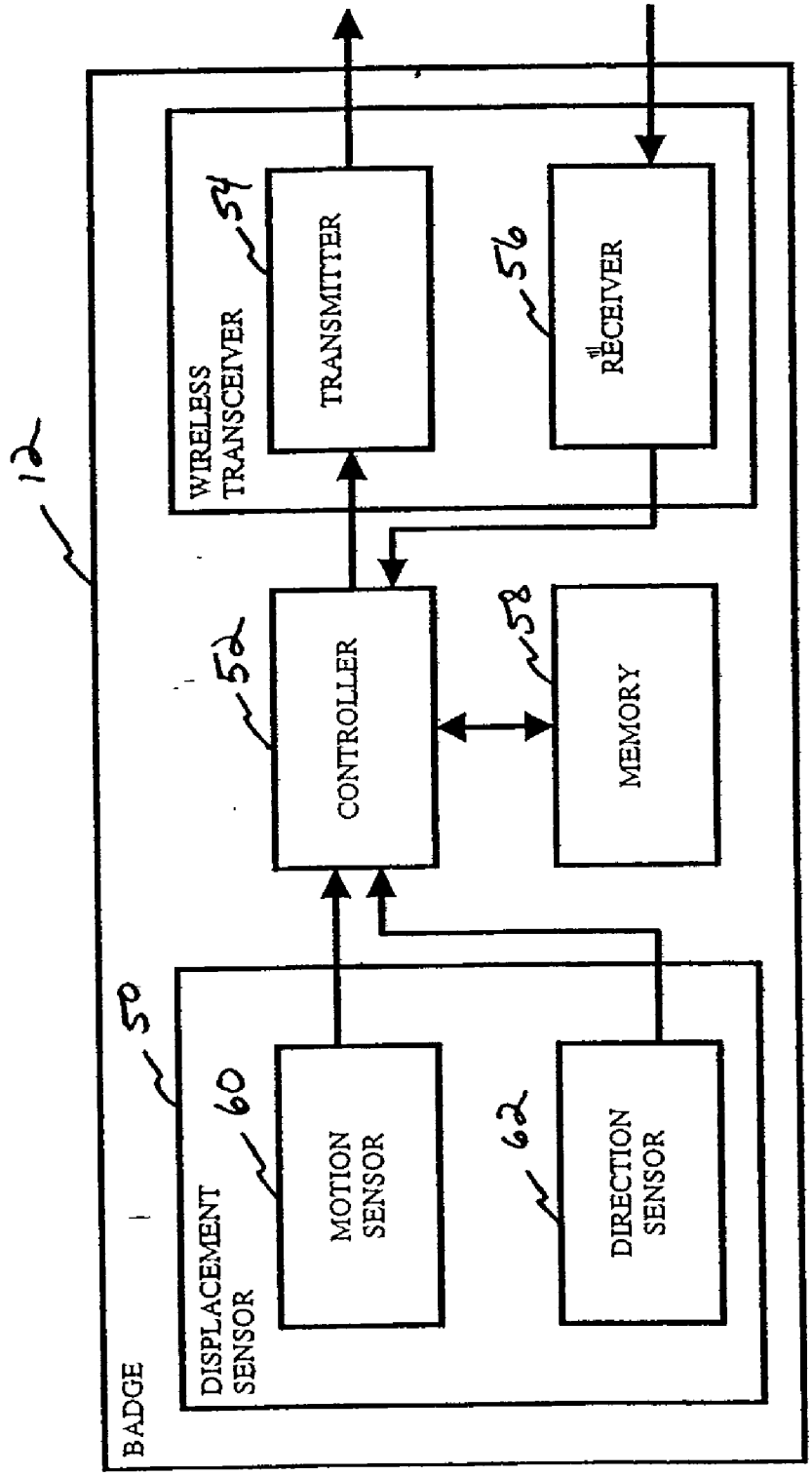
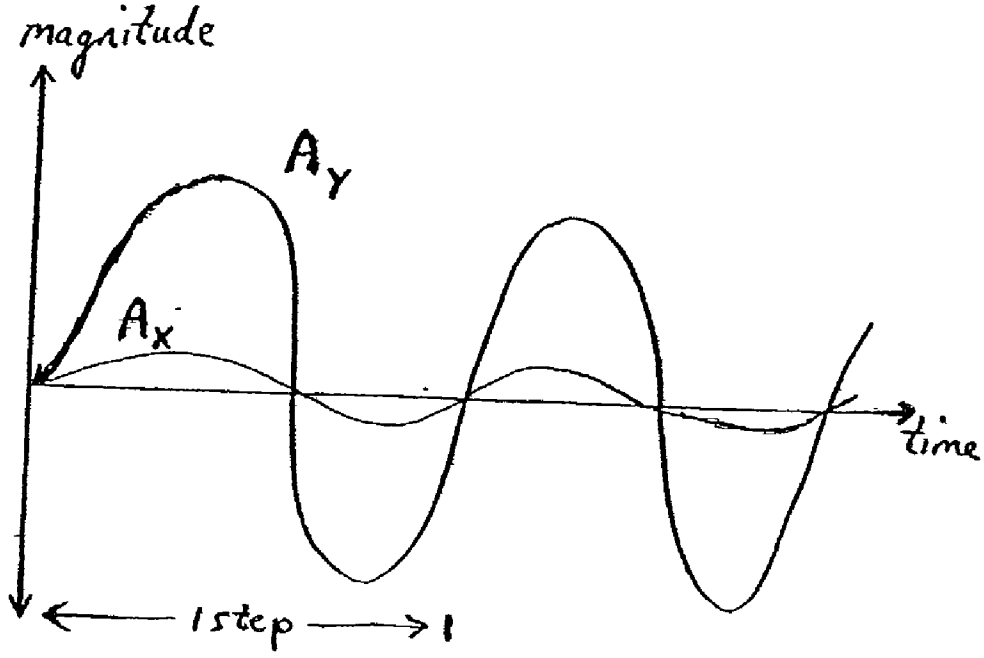

12
BADGE
50
DISPLACEMENT SENSOR
60
MOTION SENSOR
62
DIRECTION SENSOR
52
CONTROLLER
58
MEMORY
WIRELESS TRANSCEIVER
54
TRANSMITTER
56
RECEIVER

FIG. 2



Frequency ∝ Pace

FIG. 3

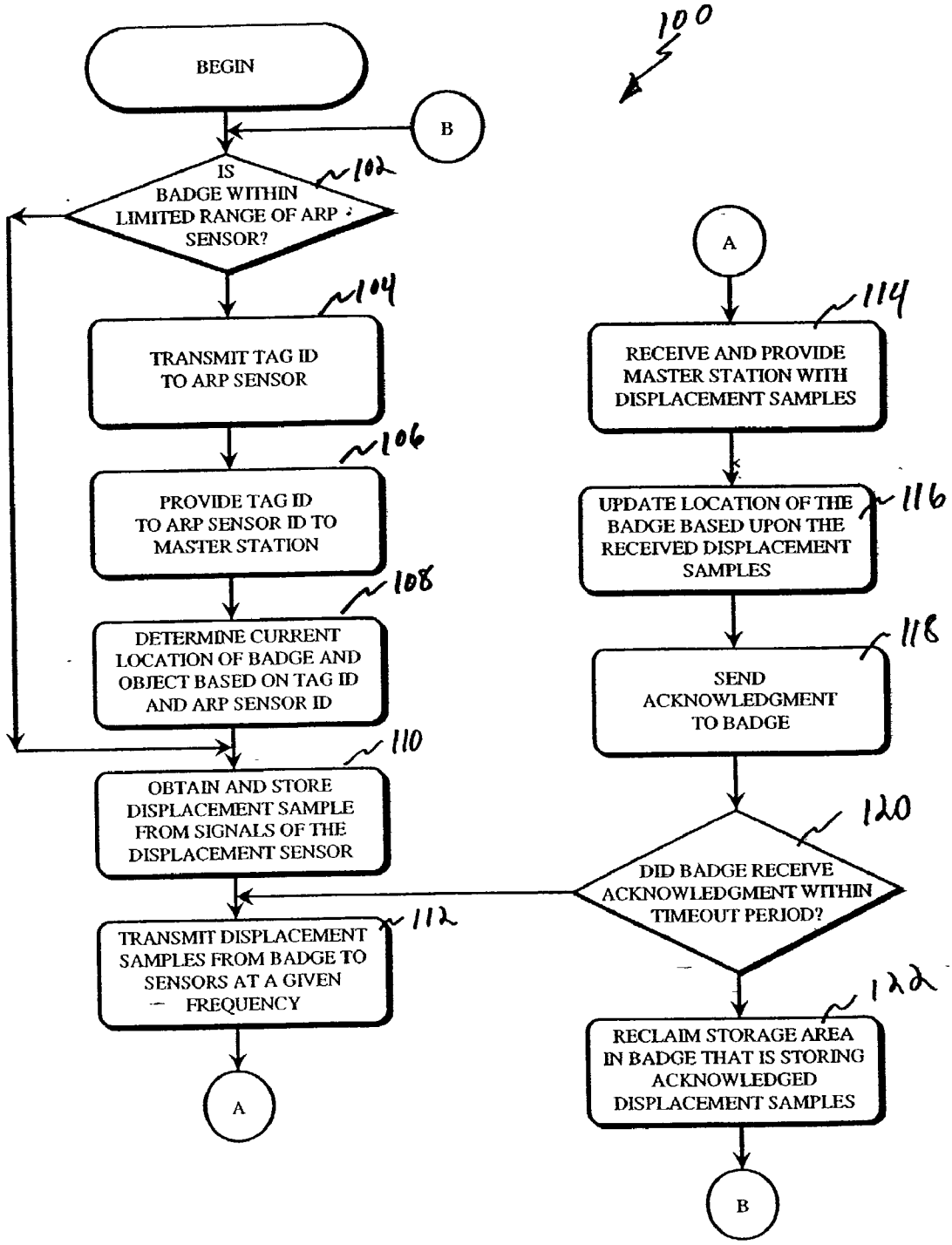

100
BEGIN
B
IS BADGE WITHIN LIMITED RANGE OF ARP SENSOR?
102
TRANSMIT TAG ID TO ARP SENSOR
104
PROVIDE TAG ID TO ARP SENSOR ID TO MASTER STATION
106
DETERMINE CURRENT LOCATION OF BADGE AND OBJECT BASED ON TAG ID AND ARP SENSOR ID
108
OBTAIN AND STORE DISPLACEMENT SAMPLE FROM SIGNALS OF THE DISPLACEMENT SENSOR
110
TRANSMIT DISPLACEMENT SAMPLES FROM BADGE TO SENSORS AT A GIVEN FREQUENCY
112
A
A
RECEIVE AND PROVIDE MASTER STATION WITH DISPLACEMENT SAMPLES
114
UPDATE LOCATION OF THE BADGE BASED UPON THE RECEIVED DISPLACEMENT SAMPLES
116
SEND ACKNOWLEDGMENT TO BADGE
118
DID BADGE RECEIVE ACKNOWLEDGMENT WITHIN TIMEOUT PERIOD?
120
RECLAIM STORAGE AREA IN BADGE THAT IS STORING ACKNOWLEDGED DISPLACEMENT SAMPLES
122
B

FIG. 4

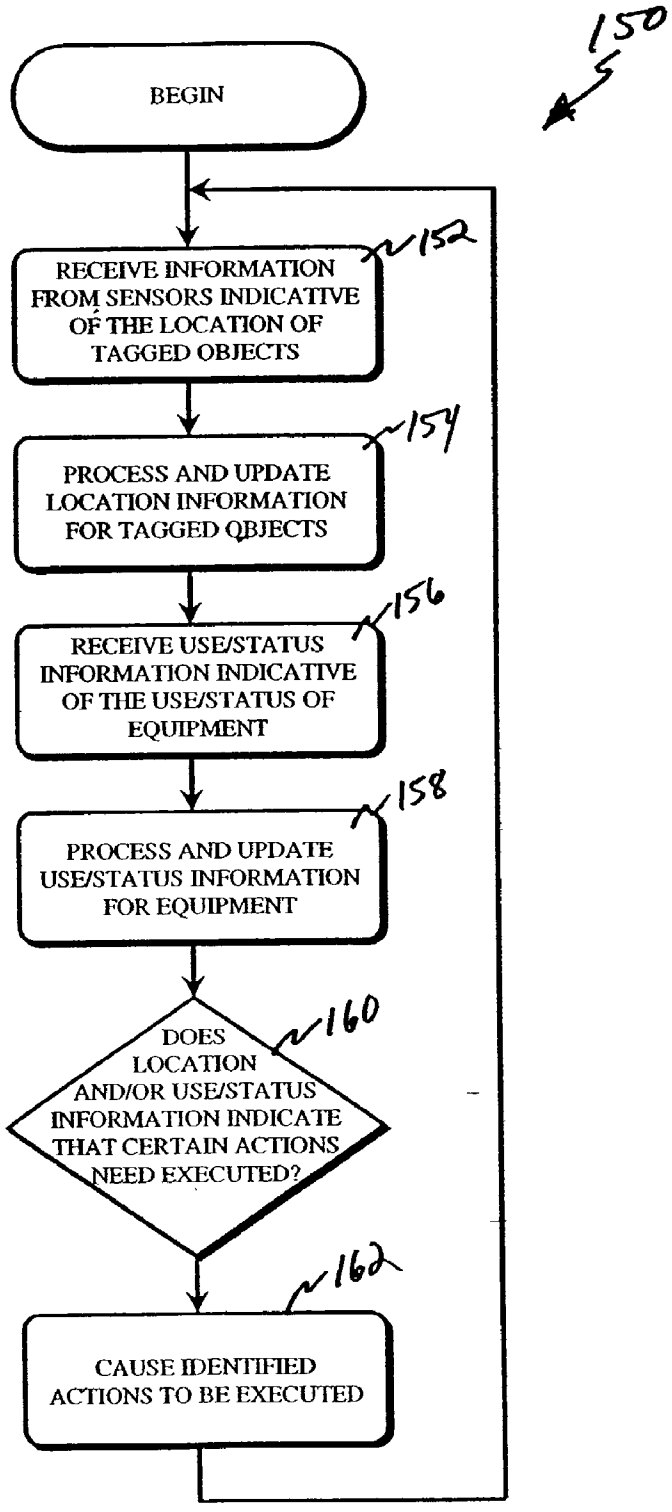

150
BEGIN
RECEIVE INFORMATION FROM SENSORS INDICATIVE OF THE LOCATION OF TAGGED OBJECTS
152
PROCESS AND UPDATE LOCATION INFORMATION FOR TAGGED QBJECTS
154
RECEIVE USE/STATUS INFORMATION INDICATIVE OF THE USE/STATUS OF EQUIPMENT
156
PROCESS AND UPDATE USE/STATUS INFORMATION FOR EQUIPMENT
158
DOES LOCATION AND/OR USE/STATUS INFORMATION INDICATE THAT CERTAIN ACTIONS NEED EXECUTED?
160
CAUSE IDENTIFIED ACTIONS TO BE EXECUTED
162

FIG. 5

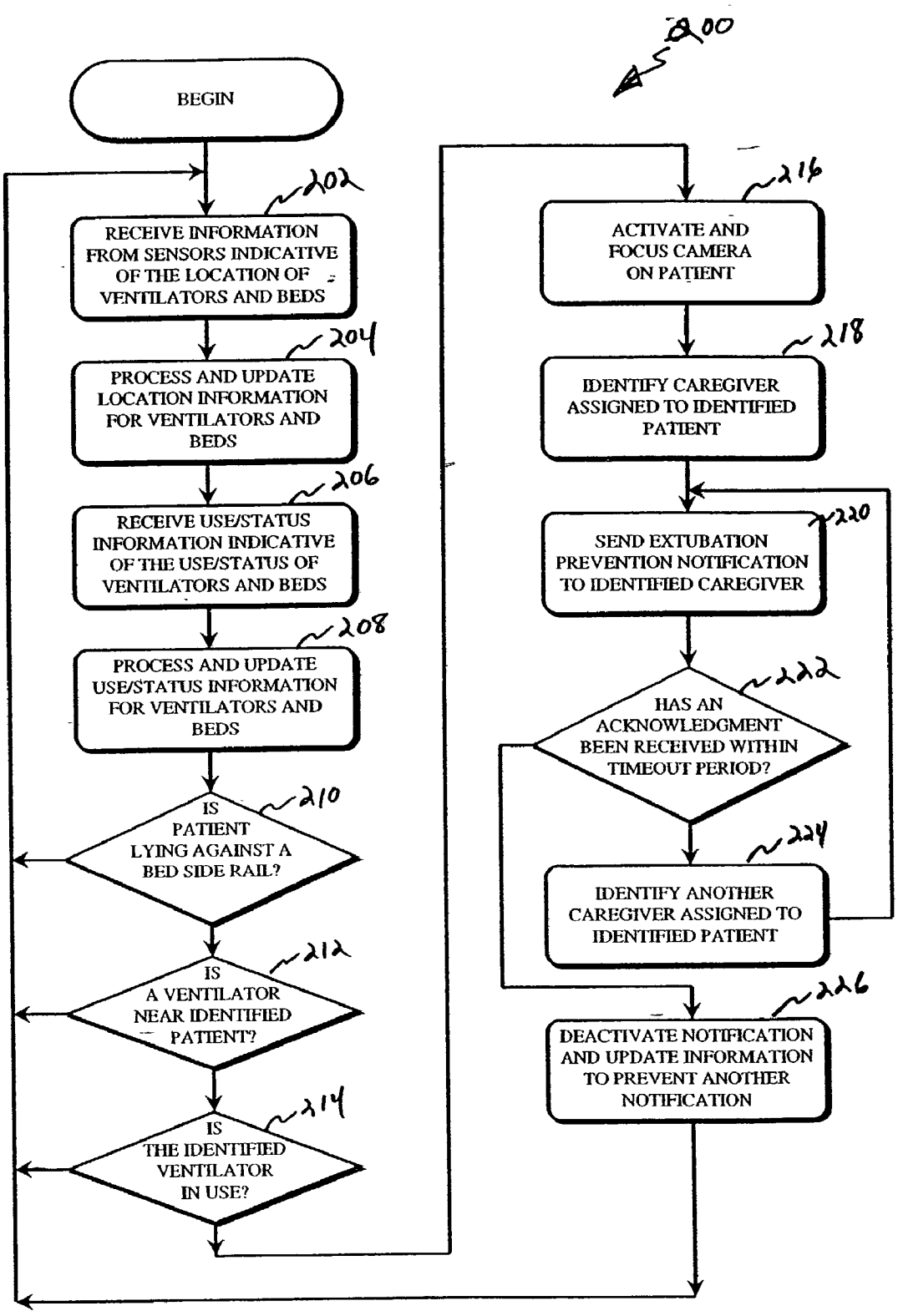

200
BEGIN
202
RECEIVE INFORMATION FROM SENSORS INDICATIVE OF THE LOCATION OF VENTILATORS AND BEDS
204
PROCESS AND UPDATE LOCATION INFORMATION FOR VENTILATORS AND BEDS
206
RECEIVE USE/STATUS INFORMATION INDICATIVE OF THE USE/STATUS OF VENTILATORS AND BEDS
208
PROCESS AND UPDATE USE/STATUS INFORMATION FOR VENTILATORS AND BEDS
210
IS PATIENT LYING AGAINST A BED SIDE RAIL?
212
IS A VENTILATOR NEAR IDENTIFIED PATIENT?
214
IS THE IDENTIFIED VENTILATOR IN USE?
216
ACTIVATE AND FOCUS CAMERA ON PATIENT
218
IDENTIFY CAREGIVER ASSIGNED TO IDENTIFIED PATIENT
220
SEND EXTUBATION PREVENTION NOTIFICATION TO IDENTIFIED CAREGIVER
222
HAS AN ACKNOWLEDGMENT BEEN RECEIVED WITHIN TIMEOUT PERIOD?
224
IDENTIFY ANOTHER CAREGIVER ASSIGNED TO IDENTIFIED PATIENT
226
DEACTIVATE NOTIFICATION AND UPDATE INFORMATION TO PREVENT ANOTHER NOTIFICATION

FIG. 6

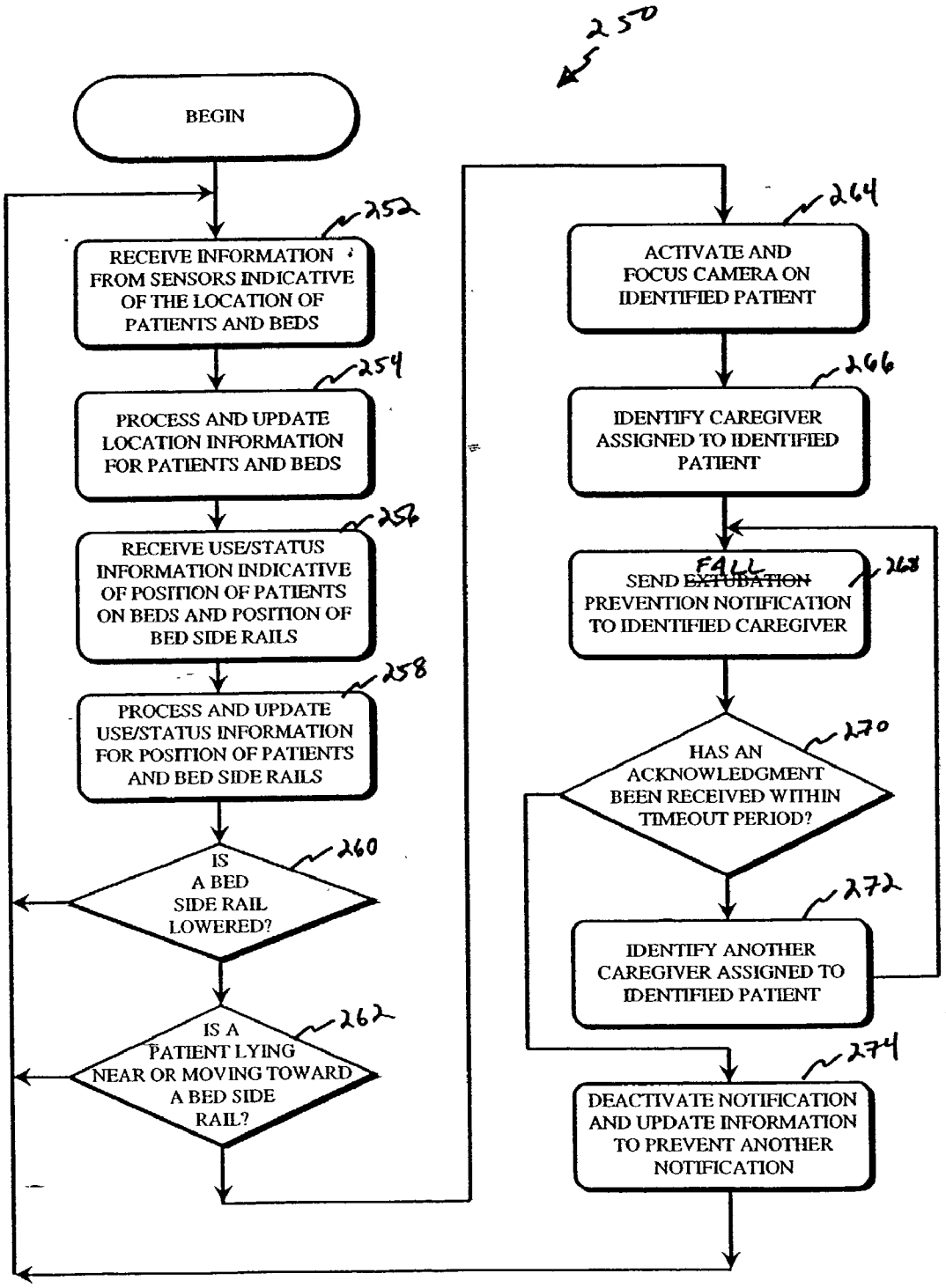

250
BEGIN
252
RECEIVE INFORMATION FROM SENSORS INDICATIVE OF THE LOCATION OF PATIENTS AND BEDS
254
PROCESS AND UPDATE LOCATION INFORMATION FOR PATIENTS AND BEDS
256
RECEIVE USE/STATUS INFORMATION INDICATIVE OF POSITION OF PATIENTS ON BEDS AND POSITION OF BED SIDE RAILS
258
PROCESS AND UPDATE USE/STATUS INFORMATION FOR POSITION OF PATIENTS AND BED SIDE RAILS
260
IS A BED SIDE RAIL LOWERED?
262
IS A PATIENT LYING NEAR OR MOVING TOWARD A BED SIDE RAIL?
264
ACTIVATE AND FOCUS CAMERA ON IDENTIFIED PATIENT
266
IDENTIFY CAREGIVER ASSIGNED TO IDENTIFIED PATIENT
268
SEND FALL ~~EXTUBATION~~ PREVENTION NOTIFICATION TO IDENTIFIED CAREGIVER
270
HAS AN ACKNOWLEDGMENT BEEN RECEIVED WITHIN TIMEOUT PERIOD?
272
IDENTIFY ANOTHER CAREGIVER ASSIGNED TO IDENTIFIED PATIENT
274
DEACTIVATE NOTIFICATION AND UPDATE INFORMATION TO PREVENT ANOTHER NOTIFICATION

FIG. 7

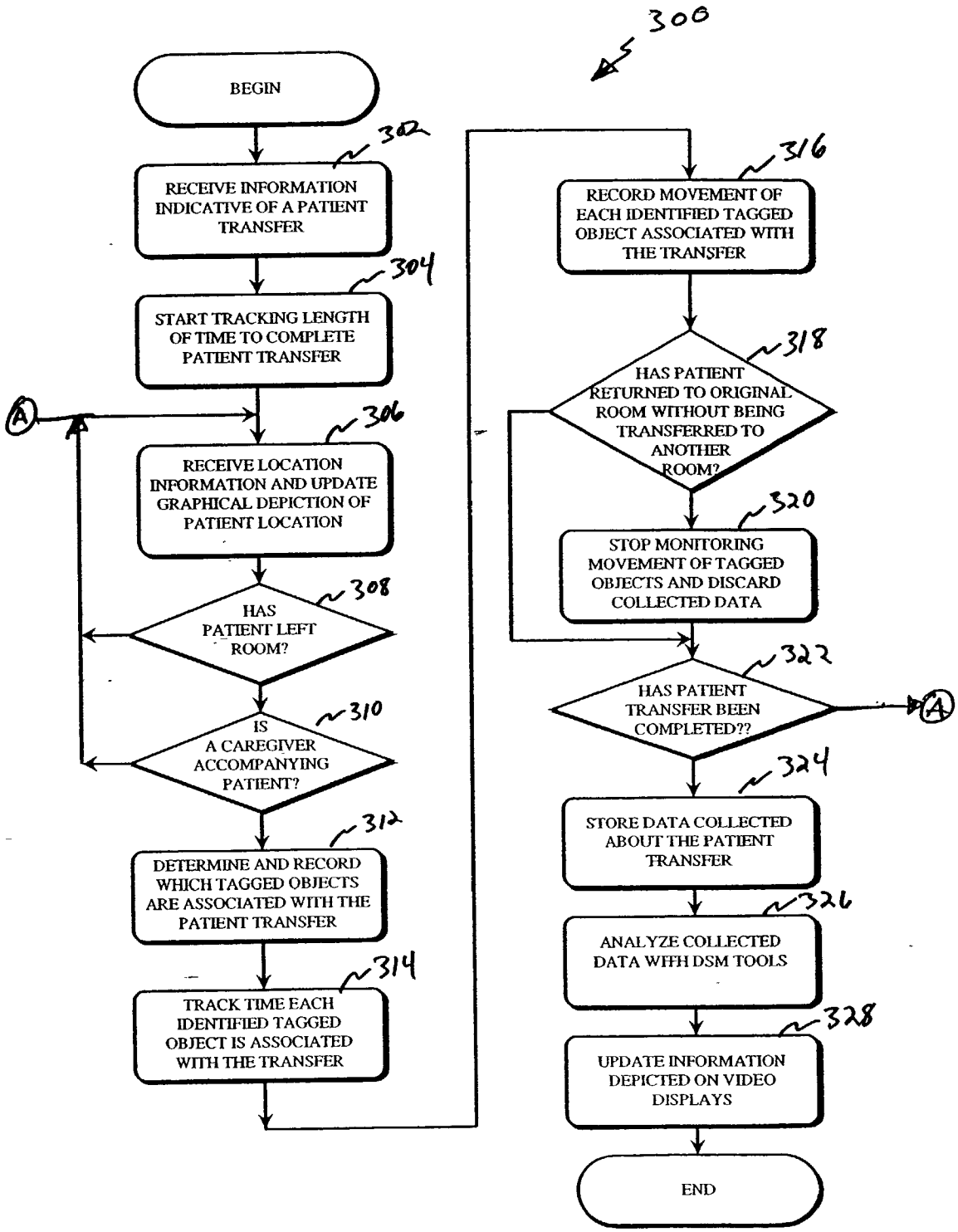

300
BEGIN
302
RECEIVE INFORMATION INDICATIVE OF A PATIENT TRANSFER
304
START TRACKING LENGTH OF TIME TO COMPLETE PATIENT TRANSFER
A
306
RECEIVE LOCATION INFORMATION AND UPDATE GRAPHICAL DEPICTION OF PATIENT LOCATION
308
HAS PATIENT LEFT ROOM?
310
IS A CAREGIVER ACCOMPANYING PATIENT?
312
DETERMINE AND RECORD WHICH TAGGED OBJECTS ARE ASSOCIATED WITH THE PATIENT TRANSFER
314
TRACK TIME EACH IDENTIFIED TAGGED OBJECT IS ASSOCIATED WITH THE TRANSFER
316
RECORD MOVEMENT OF EACH IDENTIFIED TAGGED OBJECT ASSOCIATED WITH THE TRANSFER
318
HAS PATIENT RETURNED TO ORIGINAL ROOM WITHOUT BEING TRANSFERRED TO ANOTHER ROOM?
320
STOP MONITORING MOVEMENT OF TAGGED OBJECTS AND DISCARD COLLECTED DATA
322
HAS PATIENT TRANSFER BEEN COMPLETED??
A
324
STORE DATA COLLECTED ABOUT THE PATIENT TRANSFER
326
ANALYZE COLLECTED DATA WITH DSM TOOLS
328
UPDATE INFORMATION DEPICTED ON VIDEO DISPLAYS
END

FIG. 8

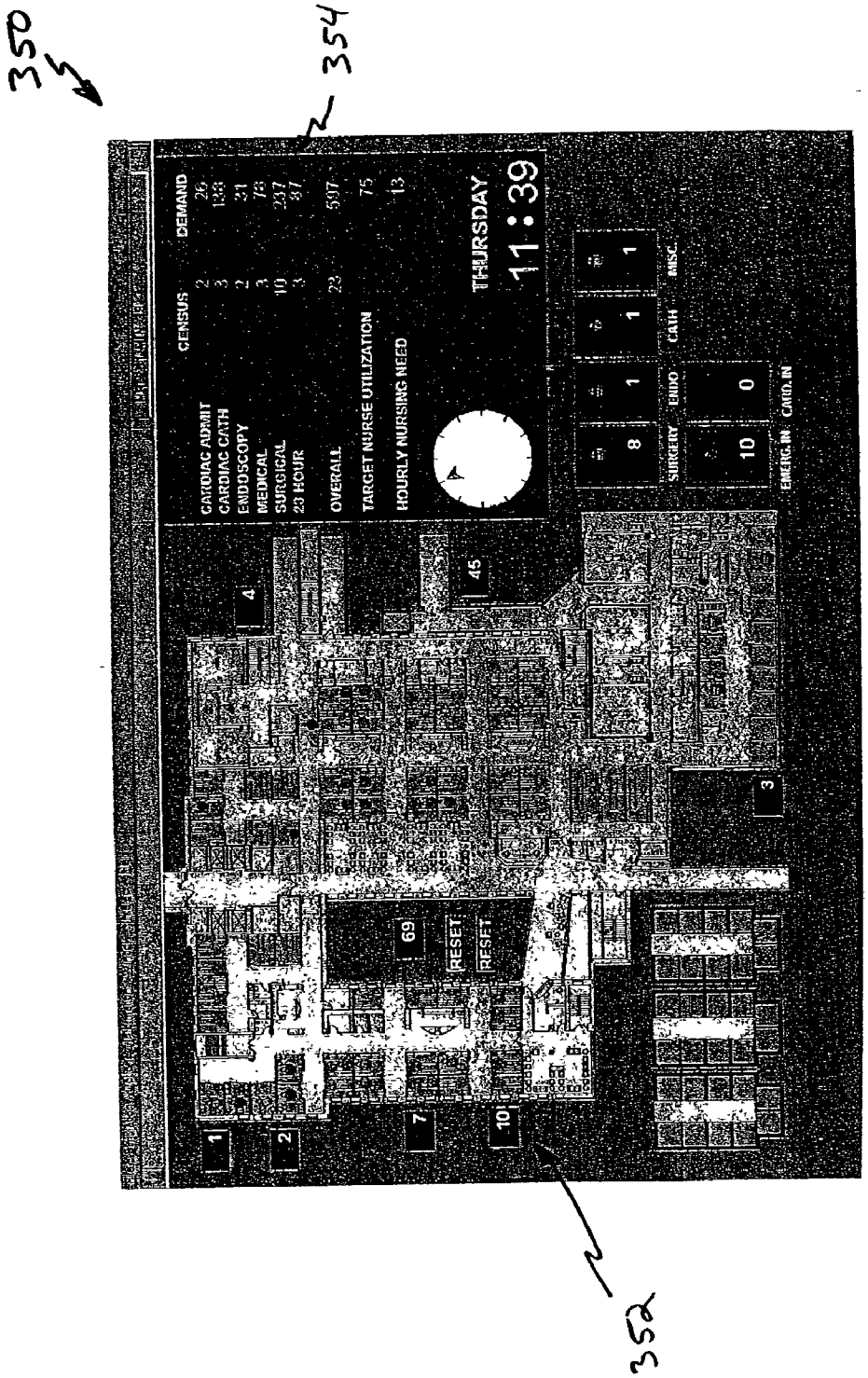

350
354
CENSUS
DEMAND
CATHAC ADMIT
CARDIAC CATH
ENDOSCOPY
MEDICAL
SURGICAL
23 HOUR
OVERALL
TARGET NURSE UTILIZATION
HOURLY NURSING NEED
THURSDAY
11:39
SURGERY
ENDO
CATH
MISC.
EMERG. IN
CATH. IN
RESET
RESET
352

FIG. 9

ARTICLE LOCATING AND TRACKING SYSTEM

[0001] This application claims priority of U.S. Patent Application Serial No. 60/289,432, filed May 8, 2001, the disclosure of which is expressly incorporated herein by reference. The present invention is related to monitoring activities and more particularly monitoring activities of persons and equipment in a healthcare environment.

TECHNICAL FIELD OF THE INVENTION

BACKGROUND AND SUMMARY OF THE INVENTION

[0002] Caregivers such as nurses and other staff in a hospital ward, hospital wing, or other healthcare facility generally work under high pressure, high stress and long hours. These caregivers should be highly responsive to patient needs, in non-emergency as well as emergency situations. Due to ever-increasing costs of healthcare and other economic practicalities, efficient deployment of the caregivers in a healthcare facility is desired, particularly at night when the number of caregivers is typically maintained at a minimum. Nevertheless, optimizing efficiency is of secondary importance relative to the primary objective of providing a high level of healthcare.

[0003] One approach to maximizing the efficiency of caregivers such as nurses in a hospital facility involves the use of a location and identification system to continuously monitor the location of the caregivers. For instance, U.S. Pat. No. 4,275,385 to White, which is incorporated herein by reference, discloses a personnel locating system where individuals to be located wear transmitters, and each transmitter transmits a signal which corresponds to the identity of the wearer. This information is relayed to and displayed at a central control unit. The information may also be displayed at remote terminals, used to control access to equipment or locations, or conveyed via a telephone interface to a telephone switching network to call the nearest telephone or to page the wearer of the transmitter. Additionally, newer communications systems provide even more than the relatively simple locating and telephoning features disclosed in White. For example, U.S. Pat. Nos. 5,561,412 to Novak et al.; 5,699,038 to Ulrich et al.; and 5,838,223 to Gallant et al., all of which are incorporated herein by reference, disclose the use of communications systems that integrate several aspects of personnel and equipment locating, call/code enunciation, and equipment status information.

[0004] As alluded to above, caregiver (e.g., nurse) to patient ratios continue to decline due to increasing economic pressures. Many healthcare facilities are exploring ways to reduce the non-value added activities of the caregivers (e.g., nurses) in order to maintain quality care while reducing the number of caregivers per patient. Computers hold promise for aiding the caregivers to work more efficiently by eliminating activities previously performed by caregivers and/or reducing the amount of time associated with the performance of caregiver activities. However, conventional uses of computers in the above locating and identification systems only supply the caregivers with information and at the most alarms indicating possible adverse events. Computer systems need to become aware of activities within the hospital environment if they are to reduce employee workload. To enable this evolution in computing technology, Activity Based Tracking ("ABT") is needed. ABT is, in a general sense, the real-time connectivity of information (i.e. location, time, and device activity, etc.) to detect the occurrence of a specific activity for which a known response is acted upon by an automated system.

[0005] Generally speaking an ABT system performs better if the ABT system includes a locating and detection system with a relatively high location resolution. In other words, the instances in which the ABT system provides value to the caregiver are increased if the ABT system is able to determine the location of caregivers, patients, equipment, etc. with high resolution. Current tracking/locating systems used in hospitals are based on IR/RF in which the location of the fixed receiver determines the location of the tagged object. Utilizing this strategy, to increase the locating resolution (e.g., to move from being able to determine which room a caregiver is in to being able to determine that the caregiver is next to a patient's bed), additional receivers with limited range must be employed.

[0006] Pursuant to a first embodiment of the present invention there is provided a badge for tagging objects for use with a locating and/or activity based tracking system. The locating and/or activity based tracking system includes a master station and absolute reference point sensors that are in communication with the master station. The absolute reference point sensors are configured to receive tag ID information from the badge whenever the badge passes within a predefined range of the absolute reference point sensor. The absolute reference point sensors provide the master station with the received tag ID information and information identifying the particular absolute reference point sensor that received the tag ID information. From this received information, the master station determines a reference location for the badge and the associated tagged object that corresponds to the absolute reference point sensor that received the tag ID information. The badge further includes a displacement sensor that generates signals indicative of motion and heading of the badge. The transmitter periodically transmits the motion and heading information to the master station which enables the master station to update the location of the object in relation to a previously known location for the object.

[0007] Pursuant to another embodiment of the invention there is provided an activity based tracking system that aids a caregiver in preventing an extubation of a patient. In general, a master station of the activity based tracking system uses information received from badges and equipment sensors to detect whether a patient who is using a ventilator is lying near or against a side rail of a bed. If the master station determines that a patient who is using a ventilator is lying near or against a side rail of a bed, then the master station causes a extubation prevention notification to be sent to the caregiver assigned to the identified patient.

[0008] Pursuant to another embodiment of the invention there is provided an activity based tracking system that aids a caregiver in preventing a patient from falling from bed. In general, a master station of the activity based tracking system uses information received from badges and equipment sensors to detect whether a patient is lying near or moving toward a bed side rail that is in a down position. If the master station determines that a patient is lying near or

moving toward a bed side rail in the down position, then the master station causes a fall prevention notification to be sent to the caregiver assigned to care for the identified patient.

[0009] Pursuant to another embodiment of the invention there is provided an activity based tracking system that aids in gathering data for a simulation modeling tool. In general, a master station of the activity based tracking system continually receives information from badges, equipment sensors, and absolute reference position sensors. If the master station determines that the information is associated with an activity for which the master station has been preconfigured to gather data for later simulation modeling, then the master station records the received data. The master station further tracks the length of time to complete activities and the length of time tagged objects participate in the activity.

[0010] Additional features and advantages of the present invention will be evident from the following description of the drawings and exemplary embodiments.

BRIEF DESCRIPTION OF THE DRAWINGS

[0011] **FIG. 1** illustrates an exemplary activity based tracking system that incorporates various features of the present invention;

[0012] **FIG. 2** illustrates an exemplary badge of the activity based tracking system shown in **FIG. 1**;

[0013] **FIG. 3** illustrates typical movement of the badge shown in **FIG. 2** when a object tagged with the badge is in transit;

[0014] **FIG. 4** illustrates an exemplary location method used by the activity based tracking system of **FIG. 1** to determine the location of tagged objects based upon information received from the badges of the tagged objects;

[0015] **FIG. 5** illustrates an exemplary activity based tracking method used by the activity based tracking system of **FIG. 1** to perform activity based tracking;

[0016] **FIG. 6** illustrates an exemplary extubation prevention method which is a particular embodiment of the activity based tracking method shown in **FIG. 5**;

[0017] **FIG. 7** illustrates an exemplary fall prevention method which is a particular embodiment of the activity based tracking method shown in **FIG. 5**;

[0018] **FIG. 8** illustrates an exemplary modeling simulation method which is a particular embodiment of the activity based tracking method shown in **FIG. 5**; and

[0019] **FIG. 9** illustrates an exemplary display generated by the activity based tracking system of **FIG. 1**.

DETAILED DESCRIPTION OF EXEMPLARY EMBODIMENTS

[0020] While the invention is susceptible to various modifications and alternative forms, exemplary embodiments thereof have been shown by way of example in the drawings and will herein be described in detail. It should be understood, however, that there is no intent to limit the invention to the particular forms disclosed, but on the contrary, the intention is to cover all modifications, equivalents, and alternatives falling within the spirit and scope of the invention as defined by the appended claims.

[0021] **FIG. 1** illustrates an exemplary activity based tracking (ABT) system **10** which incorporates various features of the present invention therein. In general, the ABT system **10** is operable to monitor activities and cause execution of actions in response to various activities. The exemplary ABT system **10** includes badges **12** used to tag persons **14** and equipment such as beds **16** and ventilators **18**. As further described below, badges **12** may include passive RFID, active RF, or active IR transmitters. The exemplary ABT system **10** also includes short range absolute reference position (ARP) sensors **20** operable to communicate with badges **12** and long range sensors **22** operable to communicate with badges **12**. As further described below, sensors **20**, **22** may include passive RFID, active RF, or active IR sensors. The exemplary ABT system **10** further includes equipment sensors **24** operable to provide use and/or status information associated with equipment such as beds **16**, ventilators **18**, and bed side rails **26**. The exemplary ABT system **10** also includes video displays **28**, an optional reference field generator **30**, video cameras **32**, and a master station **34**.

[0022] The master station **34** is generally operable to receive information from the badges **12** and the equipment sensors **24**, process the received information, and cause some action to be taken in response to determining that the received information satisfies predefined criteria or rules. The master station **34** includes memory **36**, a processor **38**, a transceiver **40**, and software stored in the memory **36**. The software when executed by the processor **38** generally causes the master station **34** to monitor persons **14** and equipment and cause certain actions to be taken in response to activities of the persons **14** and equipment. More details concerning the types of activities monitored, the manner of monitoring the activities, and the types of actions taken in response to the monitored activities are described below with reference to FIGS. **4-8**.

[0023] As illustrated, the exemplary master station **34** is essentially a centralized computing system that executes software that causes the master station **34** to implement appropriate logic for activity based tracking. However, the master station **34** may alternatively be implemented in a distributed manner with multiple computing systems working together to implement the logic. In particular, the master station **34** may be implemented with a server cluster or server farm comprising several computing systems. Moreover, the master station **34** may also incorporate computational power of hospital equipment distributed throughout the facility such as beds, monitoring devices, docking stations, etc. in order to distribute portions of the computational burden associated with the logic to many processors.

[0024] The transceiver **40** of the master station **34** is coupled to the ARP sensors **20** and long range sensors **22** via a computer network or direct wiring in order to receive and/or transmit information therebetween. Moreover, the transceiver **40** of an exemplary embodiment is also coupled to some of the equipment sensors **24** via a computer network or direct wiring in order to receive and/or transmit information therebetween. Alternatively, the transceiver **40** includes wireless transmitters and receivers in order to wirelessly communicate with some or all of the ARP sensors **20**, long range sensors **22**, and/or the equipment sensors **24**.

[0025] The optional reference field generator **30** is generally operable to provide a reference field from which the

badges **12** generate heading information. As described below, the exemplary badges **12** include magnetoresistive sensors that provide signals indicative of the sensors' orientation to a reference field such as Earth's magnetic field. The reference field generator **30** is typically configured to generate a stronger magnetic field than the Earth's magnetic field. As a result, the badges **12** used with the reference field generator **30** typically include a low cost magnetoresistive sensor that does not require tilt detection or tilt correction.

[**0026**] The video displays **28** of the ABT system **10** are positioned at various locations throughout the facility (e.g., nurses' stations, hallways, utility rooms). The video displays **28** are operable to provide a graphical representation of the facility including the locations of tagged objects in the facility and the status of various equipment **15** in the facility as illustrated in **FIG. 9**. Moreover, in an exemplary embodiment, at least a portion of the video displays **28** are also operable to display representations of real-time streaming video. The video displays **28** are implemented using various display technologies such as televisions, computer CRTs, liquid crystal displays (LCDs), light emitting diodes (LEDs), and display panels. In an exemplary embodiment, handheld devices such as a Palm™ Pilots, or Handspring™ Visors which are carried by the caregivers also include video displays **28**.

[**0027**] The badges **12** are generally worn by persons **14** (e.g., doctors, nurses, interns, orderlies, visitors, etc.) or attached to equipment to be monitored (e.g., beds **16**, ventilators **18**, IV pumps, etc). The badges **12** and the sensors **20**, **22** generally each include a receiver, a transmitter, a combination transmitter and receiver, a transceiver, or other receiving or transmitting mechanisms suitable for communicating information between the badges **12** and the sensors **20**, **22**. In an exemplary embodiment, the badges **12** are operable to send information such as a tag ID that uniquely identifies a given badge **12** and/or displacement information indicative of motion and heading of the badge to the sensors **20**, **22**. Moreover, the badges **12** of the exemplary embodiment are further operable to receive information such as an acknowledgment from the sensors **20**, **22**.

[**0028**] The sensors **20**, **22** of the exemplary ABT system **10** generally include a receiver operable to receive information transmitted by badges **12**. The sensors **20**, **22** are also generally operable to forward the information received to the master station **34** and/or provide the master station **34** with a sensor ID that uniquely identifies the sensor **20**, **22**. The sensor ID enables the master station **34** to track the location of each tagged object (i.e., person **14** or equipment) based upon which sensors **20**, **22** received information from the badges **12** of tagged objects as the tagged objects move through the facility.

[**0029**] According to one embodiment of the invention, a person **14** may enter a floor of a hospital wearing a badge **12**. The system recognizes that person **14** has entered the floor when person **14** moves within range of ARP sensor **20**, whereupon the passive RFID of badge **12** was activated and transmitted an ID associated with badge **12** (and person **14**). The ID was received by an sensor **20** including an RFID integrator located at a doorway entrance to the floor. As further explained herein, the network establishes an initial location point for person **14** by knowing the specific location of the RFID integrator. The RFID integrator may also be configured to transmit, for example, patient assignments to person **14**, which are received by badge **12** and stored in badge memory **36**. The system may then detect person **14** in a hallway of the floor with a sensor **22** including an active RF sensor for detecting ID signals transmitted by badge **12** with an active RF transmitter that periodically transmits the ID signal (e.g., every **5** seconds). As person **14** enters a patient room, the system may detect three signals from person **14** (i.e., an active RF signal indicating that person **14** is on the floor, an active IR signal indicating that person **14** is in a specific patient room, and a passive RFID signal indicating that person **14** is in the door entryway to the specific patient room. By installing RFID integrators at different locations within such patient rooms, the system may accomplish increased resolution regarding the location of person **14** within the room.

[**0030**] In an exemplary embodiment, each badge **12** includes a passive RF transmitter which is fully or partially powered by an ARP sensor **20** when in close proximity with the ARP sensor **20** (e.g., within **3** feet). In response to being in close proximity to the ARP sensor **20**, the passive RF transmitter of the exemplary badges **12** transmits the identification signal to the ARP sensors **20**. For example, the RF transmitter of a badge **12** transmits the identification signal to an RF receiver of an ARP sensor **20** in the doorway of patient room A when the badge **12** passes through the doorway of the patient room A. The ARP sensor **20** then provides information identifying the particular badge **12** to the master station **34** and information identifying the particular ARP sensor **20** for further processing and recording. In an exemplary embodiment, the ARP sensor **20** includes an RF identification receiver or a limited focus IR receiver. In general, the ARP sensor **20** enables the master station **34** to establish a very specific location of a badge **12**. More specifically, the ARP sensors **20** are used by the master station **34** to re-calibrate the location of the badges **12** as they pass within close proximity of the ARP sensors **20**.

[**0031**] In one embodiment of the ABT system **10**, visitors and patients are also provided with badges **12** to enable the master station **34** to monitor their movements through the facility. In such an embodiment, visitors and patients are given active badges which actively transmit an identification signal. In an alternative embodiment, visitors and patients are given passive badges which transmit an identification signal when in close proximity to one of the ARP sensors **20** located throughout the facility.

[**0032**] The badges **12** may also be attached to equipment (e.g., IV pumps, beds **16**, ventilators **18**, carts, diagnostic equipment, or the like) to be monitored by the ABT system **10** and generally enable the location of equipment to be tracked throughout the facility. As a result of providing the ABT system **10** with information concerning the location of equipment, the ABT system **10** causes actions to be executed based upon the location of the equipment and/or persons' interactions with such equipment.

[**0033**] The equipment sensors **24** are generally associated with equipment and generally enable the ABT system **10** to monitor the use and/or status of such equipment. For example, equipment sensors **24** are attached to the electrical plugs of the equipment to determine whether the equipment is drawing a current. In an exemplary embodiment, the badges **12** that are attached to certain equipment further

include equipment sensors **24**. The equipment sensors **24** enable the ABT system **10** to cause actions to be executed based upon use and/or status of the equipment. Furthermore, by reporting when the equipment is activated and deactivated, the equipment sensors **24** enable the hospital to charge patients for the actual amount of time the equipment was used instead of utilizing national averages based on the type of illness of the patient.

[**0034**] In an exemplary embodiment, the badges **12** and the sensors **20**, **22** further include anti-collision technology that allows for information to be transferred between a single sensor **20**, **22** and multiple badges **12** in a simultaneous or pseudo-simultaneous (e.g., TDMA, CDMA) manner. Use of anti-collision technology allows for several badges **12** to be detected at the same time by the same sensor **20**, **22** thereby providing the ABT system **10** with the ability to identify persons **14** and equipment in close proximity to one another and accurately track their respective locations and activities.

[**0035**] Additional details concerning the structure and function of a suitable system for locating and tracking persons **14** and to support various other features of the present invention are disclosed in U.S. Pat. No. 5,561,412, the disclosure of which is hereby incorporated by reference. Other location and tracking systems are disclosed in U.S. Pat. No. 6,344,794 filed Jan. 7, 2000 and co-pending U.S. patent application Ser. No. 09/699,796, filed Oct. 30, 2000, the disclosures of which are hereby incorporated by reference. Additional location and tracking systems are disclosed in U.S. Pat. Nos. 4,275,385; 4,601,064; Re 35,035; 5,633,742; 5,745,272; 5,818,617; 5,119,104; 5,387,993; 5,548,637; 5,572,195; 5,291,399; 5,455,851; 5,465,082; 5,515,426; 5,594,786; 5,689,229; 5,822,418; 5,822,544; 5,699,038 and 5,838,223.

[**0036**] In an exemplary embodiment, the badges **12** are implemented in a manner similar to the badges described in U.S. Pat. No. 5,561,412, U.S. Pat. No. 6,344,794, and co-pending U.S. patent application Ser. No. 09/699,796 in which the location of a badge **12** is determined solely upon which sensors of the location and tracking system detect the badge **12**.

[**0037**] Alternatively, the badges **12** include components which aid in tracking the location of the badges **12** and thus enable a reduction in the number of sensors required to track the location the badges **12** in a fine grain manner. As depicted in **FIG. 2**, the exemplary badges **12** include a displacement sensor **50**, a controller **52**, a transmitter **54**, a receiver **56**, and a memory **58**. The displacement sensor **50** is configured to generate one or more signals the combination of which is indicative of a motion and a heading of a "tagged object." As indicated above, tagged objects include persons (e.g., doctors, nurses, orderlies, visitors, etc.), and equipment (e.g., a hospital bed **16**, IV pumps, ventilators **18**, heart monitors, medication containers, charts, portable televisions, etc.), or any other tangible thing desired to be located and/or tracked.

[**0038**] As depicted, the displacement sensor **50** generally comprises a motion sensor **60** and a direction sensor **62**. The motion sensor **60** is generally operable to sense movement of the tagged object and generate one or more signals that in combination are indicative of the sensed movement. The motion sensor **60** includes a mono-axis, dual-axis, or tri-axis accelerometer which generates one or more signals that in combination are indicative of the dynamic acceleration (e.g., vibration induced acceleration) and/or static acceleration (e.g., gravity induced acceleration) of the tagged object. In particular, the motion sensor **60** of the exemplary embodiment includes an ADXL202 accelerometer from Analog Devices which is a low cost, low power, complete 2-axis accelerometer with a measurement range of ±2 g. The ADXL202 accelerometer measures both dynamic acceleration (e.g., vibration) and static acceleration (e.g., gravity) and generates a first Duty Cycle Modulated ("DCM") signal whose duty cycle (ratio of pulsewidth to period) is proportional to the acceleration in a first sensitive axis (e.g., x-axis) and a second DCM signal whose duty cycle is proportional to acceleration in a second sensitive axis (e.g., y-axis).

[**0039**] The following Analog Devices publications further describe the ADXL202 accelerometer and methods for relating the sensed accelerations to distances traveled: "ADXL202/ADXL201—Low cost ±2 g/±10 g Dual Axis iMEMS® Accelerometers with Digital Output" (Datasheet, Rev. B—4/99) and "Using the ADXL202 in Pedometer and Personal Navigation Applications," by Harvey Weinberg, the disclosures of which are hereby incorporated herein by reference.

[**0040**] The direction sensor **62** of the displacement sensor **50** is generally operable to generate one or more signals that in combination are indicative of the directional orientation or heading of the badge **12** with respect to a reference direction and therefore indicative of the direction traveled by the object tagged with the badge **12**. The direction sensor **62** of the exemplary embodiment includes a two-dimensional magnetoresistive field sensor such as the Philips KMZ52 sensor or two one-dimensional magnetoresistive field sensors such as the Philips KMZ51 which generate one or more signals indicative of the horizontal orientation of the badge **12** with respect to a reference direction such as magnetic north, true north, or some other direction defined by an associated reference field such as the Earth's magnetic field or an artificially generated field such as that generated by reference field generator **30**. The exemplary direction sensor **38** further includes support electronics such as a flip coil driver and pre-amps which are used to calibrate the field sensors and interface the field sensors with the controller **32** as explained in Philips Semiconductor publication "Electronic Compass Design using KMZ51 and KMZ52, Application Note AN00022, dated Mar. 30, 2000.

[**0041**] As indicated above, the exemplary ABT system **10** includes a reference field generator **30** that enables the badge **12** to be implemented without tilt correction. However, in an alternative exemplary embodiment, the direction sensor **62** further includes mechanical or electrical gimbaling components that maintain the two sensitive axes of the field sensor in a horizontal plane (e.g., maintain an x-axis and a y-axis perpendicular with Earth's gravity). To support electronic gimbaling or tilt compensation, the direction sensor **62** includes a three-dimensional field sensor and a pitch-and-roll sensor. The three-dimensional field sensor includes three sensitive orthogonal axis sensors that generate one or more signals which in combination are indicative of a three-dimensional spatial orientation of the badge **12** with respect to a reference field such as Earth's magnetic field or a generated field such as that generated by the reference field generator **30**. Further, the pitch-and-roll sensor generates

one or more signals indicative of the orientation of the field sensor with respect to gravity. In particular, the pitch-and-roll sensor includes a two-dimensional accelerometer, such as the ADXL202 accelerometer described above, including two orthogonal axis sensors that generate one or more signals. These signals, in combination, are indicative of the static acceleration experienced by the badges **12** due to gravity.

[**0042**] The transmitter **54** of the badges **12** is coupled to the controller **32** to receive one or more signals indicative of information to be transmitted. Similarly, the receiver **56** is coupled to the controller **52** to provide the controller **52** with one or more signals indicative of information received. The transmitter **54** and the receiver **32** include infrared (IR), radio frequency (RF), and/or other wireless transmission and reception components which utilize one or more different transmission protocols. More specifically, as indicated above, the transmitter **52** includes a passive RF transmitter to transmit identification information such as a tag ID to the ARP sensors **20**. Passive RF transmitters i) do not require battery power to transmit information, and ii) generally must pass close to an ARP sensor **20** in order to transmit information which insures a high resolution point for the absolute position.

[**0043**] The controller **52** in general controls the transmission and reception of information to and from the badges **12**. In an exemplary embodiment, the controller **52** is implemented with a low cost microcontroller such as the Micro-Chip PIC16C54. Besides controlling the transmission and reception of information to and from the badges **12**, the controller **52** also processes the displacement signals received from the displacement sensor **50** and stores displacement samples in the memory **58** that are representative of the motion and heading of the badges **12** as sensed by the displacement sensor **50**. In particular, the controller **52** in an exemplary embodiment processes one or more motion signals from the displacement sensor **50** to obtain motion data that is indicative of the speed of the badge **12** and heading data indicative of the heading of the badges **12**.

[**0044**] **FIG. 3** shows waveforms representing an exemplary vertical acceleration, "A_y," and an exemplary horizontal acceleration, "A_x," of a person walking or running. In general, pedestrian travel is fairly rhythmic pursuant to the gait of the pedestrian. Accordingly, as the person walks or runs through the facility, the badge **12** attached to the person is accelerated vertically and horizontally in generally periodic fashions. Each step or stride taken by the person is detectable as the period of A_y. Thus, the frequency of A_y is proportional to the number of steps taken by the caregiver per unit of time, which is proportional to the approximate pace at which the person walks or runs.

[**0045**] In the exemplary embodiment discussed above in connection with **FIG. 2**, the controller **52** receives one or more signals from the displacement sensor **50** that are indicative of the vertical acceleration A_y. In the exemplary embodiment, the controller **52** determines the approximate speed of movement of the person by processing the received signals to obtain the frequency of the vertical acceleration A_y which is indicative of the speed of the person.

[**0046**] In the case of a wheeled objects or an object on skids (e.g., hospital beds **16**, carts, tables, etc.) the accelerations imparted to the tag or badge **12** attached to the object are fairly periodic in nature due to each revolution of the wheel(s) or vibrations of the skid(s). In an exemplary embodiment, a ridge or a bump is added to a wheel of a wheeled object in order to aid in the generation of a discernable amount of acceleration. In any event, although the relationship of the vertical acceleration A_y, horizontal acceleration A_x, and time may vary between different types of assets, and even between different pedestrians, the fairly periodic nature of the accelerations imparted to the badges **12** while the object is in motion are readily discernable via the appropriate signal processing algorithms. Moreover, the displacement sensor **50** may generate the signals based on other parameters that vary with the speed of movement of the object. For example, the displacement sensor **50** for wheeled assets may include a more conventional type speedometer that senses the rotation of the wheels and generates signals based upon the sensed rotation of the wheels.

[**0047**] In an exemplary embodiment, the master station **34** receives the displacement samples from the badges **12** and further processes the displacement samples to obtain an estimated distance traveled and an estimated heading traveled. In particular, the master station **34** determines the estimated distance traveled based upon the motion data received from the badges **12** in a manner similar to one of the methods described in "Using the ADXL202 in Pedometer and Personal Navigation Applications," by Harvey Weinberg. The master station **34** also determines an estimated heading traveled from the motion data and/or the heading data received from the badges **12**. In particular, the master station **34** performs one or more of the following functions on the motion data and/or the heading data: offset-elimination, temperature drift compensation, non-orthogonality correction of sensor axes, interference field correction, declination compensation, tilt compensation, and true north compensation in a manner similar to those described in "Electronic Compass Design Using KMZ51 and KMZ52." Alternatively, the controller **52** of the badges **12** may be implemented with a more powerful processor which executes software or firmware instructions to implement all or portions of the functions performed on motion data and/or heading data described above.

[**0048**] Shown in **FIG. 4** is a location tracking method **100** used to track the location of objects tagged with badges **12**. In step **102**, the badge **12** determines whether the badge **12** is within the limited range of an ARP sensor **20**. If the badge **12** is within range of the ARP sensor **20**, then the badge **12** in step **104** transmits a tag ID to the ARP sensor **20** that uniquely identifies the badge **12**. More specifically, the badge **12** includes a passive RF transmitter that is powered by the ARP sensors **20** when in range of the ARP sensors **20**. Accordingly, the badge **12** determines that the badge **12** is within range of the ARP sensor **20** if the transmitter **54** of the badge **12** is powered by the ARP sensor **20**. In step **104**, the ARP sensor **20** that receives the information from the badge **12** provides the master station **34** with the tag ID received from the badge **12** and a sensor ID that identifies the ARP sensor **20**.

[**0049**] In a power saving embodiment of the badge **12**, the ARP sensor **20** in step **104** further causes the badge **12** to power active portions of the badge **12** (e.g., displacement sensor **50**, controller **52**) with an on-board battery (not shown). In particular, after receiving power from the ARP sensor **20** and initiating battery operation of the active

portions, the badge **12** continues to power the active portions until the controller **52** detects a power off condition. For example, the controller **52** may remove battery power from the active portions of the badge **12** after determining that the badge **12** has not received transmissions from the sensors **20**, **22** for a predetermined time period (e.g., 10 minutes), and/or that the badge **12** has been static (i.e., substantially still) for a predetermined time period (e.g., 5 minutes).

[**0050**] In step **106**, the master station **34** determines the location of the badge **12** and associated tagged object from the tag ID and the sensor ID. More specifically, the master station **34** includes facility map information that defines the location of doorways, walls, ARP sensors **20**, and other static features of the facility. From the facility map information and the information received from the ARP sensor **20** in step **104**, the master station **34** determines that the current location of the tagged object is the ARP sensor **20** identified by the received sensor ID.

[**0051**] The badge **12** in step **108** starts transmitting displacement samples at a predetermined interval (e.g., every 5 seconds). In an exemplary embodiment, the badge **12** transmits signals representative of the tag ID and all displacement samples that have been stored in the memory **58** since receiving an acknowledgment of a prior displacement sample transmission. In an exemplary embodiment, the controller **52** obtains displacement samples from the displacement signals of the displacement sensor **50** on a predetermined interval (e.g., 1 millisecond intervals) and stores the obtained displacement samples in the memory **58**. In particular, the controller **52** periodically samples the received displacement signals during the given interval to obtain displacement samples that are generally representative of the displacement signals during the interval. After obtaining the displacement samples for the interval, the controller **52** stores the displacement samples in the memory **58**. In an alternative embodiment, the badge **12** transmits the displacement samples at various different intervals depending upon the rate of movement of the badge **12** as described in U.S. Patent Application No. 60/306,818, filed Jul. 20, 2001, and entitled "Locating Badge with Intelligent Transmission Based on Acceleration," the disclosure of which is hereby incorporated by reference.

[**0052**] In an alternative embodiment, the controller **52** combines displacement samples in order to reduce the number of displacement samples stored in the memory **58**. In particular, the controller **52** combines displacement samples that are temporally adjacent to one another and that do not significantly differ from one another. For example, if the controller **52** determines that the motion and heading of temporally adjacent displacement samples are within a predetermined tolerance, then the controller **52** combines the two displacement samples (e.g., averaging the samples, discarding one of the samples) to obtain a displacement sample representative of the interval associated with both displacement samples. In this manner, the controller **52** obtains a single displacement sample that is representative of several temporally adjacent displacement samples thus reducing the number of samples stored in the memory **58**.

[**0053**] Further, the controller **52** of the alternative embodiment includes timing information with the displacement samples. For example, the controller **52** includes a count value with the motion data and heading data of the displacement samples to indicate the number of samples of which the stored displacement sample is representative. Alternatively, the controller **52** includes a timestamp value with the displacement samples. The controller **52** may instead utilize other techniques for correlating the motion data and heading data of a displacement sample to a respective time interval such as including an interval sequence count with the displacement samples.

[**0054**] As a result of periodically transmitting the displacement samples and tag ID in step **112**, receivers of the sensors **22** in step **114** receive signals that are representative of the displacement samples and tag ID of the badge **12**. The sensors **22** further provide the master station **34** with information representative of the tag ID and displacement samples in step **114**.

[**0055**] The master station **34** in step **116** determines the movement path and location of the badge **12** based upon the received tag ID, displacement samples, and the previously determined location for the badge **12** (e.g., location of an ARP sensor **20**, or location determined from displacement samples). The master station **34** processes the motion data, heading data, and optionally the timing data of the displacement samples to determine the movement path of the badge **12**. Techniques for obtaining distance information from motion data are described in the previously referenced Analog Devices publications.

[**0056**] The master station **34** in step **116** further adjusts the movement path and location to prevent a conflict between the calculated movement path for the badges **12** and the layout information for the facility. For example, the calculated movement path may indicate that the tagged object passed through a wall at a location near a doorway and then proceeded down a hallway outside the doorway. The master station **34** may alter the calculated movement path to indicated that the tagged object passed through the doorway which is the more likely scenario. Methods such as fuzzy logic, neural networks, expert systems, and/or other artificial intelligence techniques for correlating location information with map information are known.

[**0057**] In response to receiving the tag ID and displacement samples from the badges **12**, the master station **34** in step **118** causes an acknowledgment to be sent to the badge **12** via a transmitter such as the RF and/or IR transmitters of the ARP sensors **20** or the long range sensors **22**. If the badge **12** receives the acknowledgment, then the controller **52** in step **120** reclaims the storage area of the memory **58** used to store the acknowledged displacement samples. However, if the controller **52** determines in step **120** that the badge **12** did not receive the acknowledgment message within a predefined timeout period (e.g., 1 second), then the controller **52** returns to step **112** in order to retransmit the tag ID and displacement samples.

[**0058**] Referring now to **FIG. 5**, there is depicted an activity based tracking method **150** implemented by the ABT system **10**. The master station **34** of the ABT system **10** in step **152** receives information from the ARP sensors **20** that is indicative of the location of tagged objects associated with the badges **12**. The master station **34** in step **154** processes the information received in step **152** and updates location information for the tagged objects associated with the badges **12** accordingly.

[**0059**] The master station **34** also receives in step **156** information from the equipment sensors **24** that is indicative

of the use/status of the equipment associated with the equipment sensors **24**. In step **158**, the master station **34** processes the information received in step **156** and updates use/status information for the equipment associated with the equipment sensors **24**.

[**0060**] The master station **34** in step **160** analyzes the updated location and use/status information to determine whether actions need to be taken in response to the received information. In particular, the master station **34** determines for each predefined rule whether all conditions associated with the rule have been satisfied. If the updated location and/or use/status information satisfies the conditions of a given rule, then the master station **34** in step **162** causes actions associated with each satisfied rule to be executed. However, if the master station **34** determines that no predefined rule has been satisfied, then the master station **34** returns to step **62** in order to process additional information from the ARP sensors **20** and the equipment sensors **24**.

[**0061**] Hygiene monitoring systems that monitor handwashing and equipment washing are disclosed in copending U.S. patent application Ser. No. 09/699,796, filed Oct. 30, 2000 and are exemplary embodiments of the activity based tracking method **100**. In particular, the hygiene monitoring systems receive information indicative of the location of caregivers and handwashing devices and use/status information indicative of the use of the handwashing devices. From this information, the hygiene monitoring systems determine whether a caregiver needs to wash their hands to maintain compliance with an established hygiene policy. The disclosure of U.S. patent application Ser. No. 09/699,796, filed Oct. 30, 2000 and entitled "Hygiene Monitoring System" is hereby incorporated by reference.

[**0062**] Referring now to **FIG. 6**, there is depicted an exemplary extubation prevention method **200** which is a particular embodiment of the ABT method **150**. Experience has shown that extubation is more likely if a patient is lying against a side rail **26** of a bed **16** while on a ventilator **18**. Extubation may result in harm to the patient and lost work time to re-establish the breathing pathway. When executing the extubation prevention method **200** of **FIG. 6**, the ABT system **10** generally determines whether a patient is using a ventilator **18** while lying against a side rail **26** of a bed **16**. If the patient is using a ventilator **18** while lying against a bed side rail **26**, then the ABT system **10** alerts a caregiver via a pocket pager or badge **12** and may provide the caregiver with streaming video of the patient via a pocket pager, badge **12** or a nearby video display **28**. With such information, the caregiver determines whether corrective action is needed in order to prevent a possible extubation.

[**0063**] The master station **34** in step **202** receives location information from badges **12** of tagged beds **16** and badges **12** of tagged ventilators **18** that is indicative of the location of the tagged beds **16** and tagged ventilators **18**. The master station **34** in step **204** processes the location information received in step **202** and updates location information for the tagged beds **16** and ventilators **18**.

[**0064**] The master station **34** of the ABT system **10** in step **206** receives use/status information from equipment sensors **24** of beds **16** and ventilators **18** that is indicative of the use and/or status of the beds **16** and ventilators **18**. More specifically, the ABT system **10** in step **206** receives use/status information from equipment sensors **24** of beds **16** that is indicative of position of patients within beds **16**. In an exemplary embodiment, the beds **16** are equipped with one or more equipment sensors **24** in the bed side rails **26** that detect weight of the patient lying against the bed side rail **26**. In an alternative embodiment, the beds **16** include a patient support surface having one more equipment sensors **24** that detect position of the patient upon the patient support surface as disclosed in U.S. Pat. No. 6,208,250, entitled "Patient Position Detection Apparatus for a Bed **16**," the disclosure of which is hereby incorporated by reference.

[**0065**] The master station **34** in step **206** also receives use/status information from equipment sensors **24** of ventilators **18** that is indicative of the usage of the ventilators **18**. In an exemplary embodiment, the ventilators **18** include one or more equipment sensors **24** that detect whether the ventilator **18** is in use. For example, the ventilators **18** include a current sensor, voltage sensor, and/or power sensor which respectively detect the presence or absence of an operating current, operating voltage, and/or operating power and provide the result of such detection to the master station **34**. Numerous other manners for detecting whether a device such as a ventilator **18** is operating are well known in the art and any may be used with the present invention.

[**0066**] The master station **34** in step **208** processes the use/status information received in step **206** and updates use/status information for the beds **16** and the ventilators **18** accordingly. More specifically, the master station in step **208** updates use/status information to indicate the current position of patients in beds **16** and which ventilators **18** of the ABT system **10** are presently being used.

[**0067**] The master station **34** analyzes the updated location and use/status information to determine whether a patient has an increased likelihood of extubation. More specifically, the master station **34** in step **210** determines whether a patient is lying against a bed side rail **26** based upon the use/status information associated with the beds **16**. If the master station **34** determines that a patient is not lying against a bed side rail **26**, then the master station **34** returns to step **202** in order to process further information received from the badges **12** and the equipment sensors **24**.

[**0068**] If the master station **34** determines that the patient is lying against a bed side rail **26**, then the master station **34** further determines whether the patient is using a ventilator **18**. In particular, the master station **34** determines whether a ventilator **18** is near the patient lying against the bed side rail **26** based upon location information associated with the ventilators **18**. In an exemplary embodiment, the master station **34** determines that the ventilator **18** is near the patient if the location information associated with the ventilator **18** indicates that the ventilator **18** is in the same room as the patient lying against the bed side rail **26**. Alternatively, the master station **34** may determine that the ventilator **18** is near the patient if the location information indicates that the ventilator **18** is within a predetermined range (e.g., **3** feet) of the patient or the bed **16** on which the patient is lying.

[**0069**] If the master station **34** determines that a ventilator **18** is not near the patient lying against the bed side rail **26**, then the master station **34** returns to step **202** in order to process further information received from the badges **12** and the equipment sensors **24**. However, if the master station **34** determines that a ventilator **18** is near the patient lying against the bed side rail **26**, then the master station **34** in step

214 determines whether the ventilator **18** near the identified patient is in use based upon the use/status information associated with the ventilator **18**.

[**0070**] If the master station **34** determines that the ventilator **18** is not in use, then the master station **34** returns to step **202** in order to process further information received from the badges **12** and the equipment sensors **24**. However, if the master station **34** determines that the ventilator **18** is in use, then the master station **34** causes actions associated with preventing extubation of the identified intubated patient lying against the bed side rail **26**. In an exemplary embodiment, the master station **34** in step **216** activates a camera **32** located in the room of the identified patient and focuses the camera **32** on the patient if not already focused on the patient. The master station **34** in step **218** identifies which caregiver is assigned to the identified patient based upon patient assignment data that the master station **34** either maintains or has access to.

[**0071**] The master station **34** in step **220** sends an extubation prevention notification to the caregiver assigned to the intubated patient lying against the bed side rail **26**. More specifically, the master station **34** causes the badge **12** of the identified caregiver to provide a tactile indiction (e.g., vibrate), an audible indiction (e.g., beep), a visual indiction (e.g., blinking LED), and/or some other indication of the possible extubation situation. Furthermore, the master station **34** provides the identified caregiver with streaming video of the patient via a hospital network system such as the system disclosed in U.S. Pat. Nos. 5,561,412, 5,699,038, and 5,838,223, the disclosures of which are hereby incorporated by reference. The streaming video enables the caregiver to assess the patient specific situation to determine without physically entering the room of the patient if intervention is required. If the streaming video indicates that intervention is not required, then the caregiver is saved a trip to the patient's room thus providing a savings of time. In an exemplary embodiment, the master station **34** causes the video stream be sent to a video display **28** located near the caregiver (such as a nurse's station, hall monitor, etc.) or to a portable pager or badge **12** carried by the caregiver which has video playback capabilities.

[**0072**] The master station **34** in step **222** determines whether an acknowledgment was received from the caregiver within a predetermined time span (e.g., 30 seconds). The ABT system **10** provides various manners for the caregiver to acknowledge the extubation prevention notification. For example, the ABT system **10** enables the caregiver to provide the acknowledgment by actuating a mechanism (e.g., switch, button) on their badges **12**, or actuating a nearby acknowledgment mechanism (e.g., switch, button) located in various locations throughout the facility such as in the patient rooms, hallways, nurses station, rest rooms, utility rooms, etc. Alternatively, the ABT system **10** enables the caregiver to provide the acknowledgment via a remote control carried by the caregiver such as the remote control disclosed in U.S. patent application Ser. No. 09/848,941, entitled "Remote Control for Hospital Bed," filed May 4, 2001, the disclosure of which is hereby incorporated by reference.

[**0073**] If the master station **34** determines that an acknowledgment was not received from the caregiver within the predetermined timeout period, then the master station **34** in step **224** identifies another caregiver assigned to the patient. The master station **34** then returns to step **220** in order to send an extubation prevention notification and accompanying video stream to the newly identified caregiver. However, if the maser station **34** determines that an acknowledgment was received from the caregiver within the predetermined timeout period, then the master station **34** in step **226** deactivates the extubation prevention notification and updates use/status information associated with the patient and/or the ventilator **18** such that another extubation prevention notification is not generated for the same patient for a predetermined time span (e.g., 5 minutes). The master station **34** then returns to step **202** in order to process further information received from the badges **12** and the equipment sensors **24**.

[**0074**] Referring now to **FIG. 7**, there is depicted an exemplary fall prevention method **250** which is another exemplary embodiment of the ABT method **100**. Experience has shown that a patient is more likely to fall out of a bed **16** if a side rail **26** of a bed **16** is in a lowered position (i.e., down). When executing the patient fall prevention method **250** of **FIG. 7**, the ABT system **10** generally detects the position of a patient in a bed **16** and the position of the side rails **26** of the bed **16**. If ABT system **10** detects that a bed side rail **26** is in a lowered position and the patient is lying near or is moving toward the lowered bed side rail **26**, then the ABT system **10** provides a caregiver with a fall prevention notification via a pocket pager or badge **12** and provides the caregiver with streaming video of the patient via a pocket pager, badge **12** or a nearby video display **28**. With such information, the caregiver can assess whether corrective action is needed in order to prevent a possible fall.

[**0075**] The master station **34** in step **252** receives location information from badges **12** of tagged patients and badges **12** of tagged beds **16** that is indicative of the location of the tagged patients and beds **16**. The master station **34** in step **254** processes the location information received in step **252** and updates location information for the tagged patients and beds **16** accordingly.

[**0076**] The master station **34** in step **254** receives use/status information from equipment sensors **24** of the beds **16** that is indicative of the position of a patient within a bed **16** and the position of bed side rails **26**. As indicated above, the beds **16** include a patient support surface having one or more equipment sensors **24** that detect the position of a patient upon the patient support surface as disclosed in U.S. Pat. No. 6,208,250. Moreover, the bed side rails **26** include one or more equipment sensor **24** that detect the position of the side rail **26** and provide information indicative of the detected position of the bed side rail **26**. In an exemplary embodiment, the bed side rails **26** are implemented as indicated in U.S. Pat. No. 6,021,533, filed on Aug. 25, 1992 and entitled "Mattress Having a Siderail Down Sensor," the disclosure of which is hereby incorporated by reference.

[**0077**] The master station **34** in step **258** processes the use/status information received in step **256** and updates use/status information for the beds **16** and the bed side rails **26** accordingly. More specifically, the master station in step **258** updates use/status information that indicates the position of patients on beds **16** and the position of bed side rails **26**.

[**0078**] The master station **34** analyzes the updated location and use/status information to determine whether a patient

has an increased likelihood of falling from a bed **16**. More specifically, the master station **34** in step **260** determines whether a bed side rail **26** is lowered based upon the use/status information received from the bed side rails **26** in step **256**. If the master station **34** determines that a bed side rail **26** is not in the lowered position (i.e., determines that the bed side rail **26** is in the raised position), then the master station **34** returns to step **252** in order to receive and process further location and use/status information. However, if the master station **34** determines that a bed side rail **26** is in the lowered position, then the master station **34** proceeds to step **262** in order to determine whether a patient is lying near or is moving toward a lowered bed side rail **26**.

[**0079**] In step **262**, the master station **34** analyzes the use/status information indicative of the position of patients within beds **16** in order to determine whether a patient is lying near or is moving toward the identified lowered bed side rails **26**. If the master station **34** determines that a patient is not lying near and is not moving toward a lowered bed side rail **26**, then the master station **34** returns to step **252** in order to process further location and/or use/status information.

[**0080**] However, if the master station **34** determines that the patient is lying near or is moving toward a lowered bed side rail **26**, then the master station **34** causes actions associated with preventing the identified patient from falling from bed **16**. In an exemplary embodiment, the master station **34** in step **264** activates a camera **32** located in the room of the identified patient and focuses the camera **32** on the patient if not already focused on the patient. The master station **34** in step **266** identifies which caregiver is assigned to the identified patient based upon patient assignment data that the master station **34** either maintains or has access to.

[**0081**] The master station in step **268** sends a fall prevention notification to the caregiver assigned to the patient lying near or moving toward the lowered bed side rail **26**. More specifically, the master station **34** causes the badge **12** of the identified caregiver to provide a tactile indiction (e.g., vibrate), an audible indiction (e.g., beep), a visual indiction (e.g., blinking LED), and/or some other indication of the possible fall situation. Furthermore, the master station **34** provides the identified caregiver with streaming video of the patient via a hospital network system such as the system disclosed in U.S. Pat. Nos. 5,561,412, 5,699,038, and 5,838,223. In an exemplary embodiment, the master station **34** causes the video stream be sent to a video display **28** located near the caregiver (such as a nurse's station, hall monitor, etc.) or to a portable pager or badge **12** carried by the caregiver which has video playback capabilities.

[**0082**] The master station **34** in step **270** determines whether an acknowledgment was received from the caregiver within a predetermined timeout period (e.g., **30** seconds). The ABT system **10** provides various manners for the caregiver to acknowledge the fall prevention notification. For example, the ABT system **10** enables the caregiver to provide the acknowledgment by actuating a mechanism (e.g., switch, button) on their badges **12** or actuating a nearby acknowledgment mechanism (e.g., switch, button) located in various location throughout the facility such as in the patient rooms, hallways, nurses station, rest rooms, utility rooms, etc.

[**0083**] If the master station **34** determines that an acknowledgment was not received from the caregiver within the predetermined timeout period, then the master station **34** in step **272** identifies another caregiver assigned to the patient. The master station **34** then returns to step **268** in order to send a fall prevention notification and accompanying video stream to the newly identified caregiver. However, if the maser station **34** determines that an acknowledgment was received from the caregiver within the predetermined timeout period, then the master station **34** in step **274** deactivates the fall prevention notification and updates use/status information associated with the patient, the bed **16**, and/or bed side rails **26** such that another fall prevention notification is not generated for the same patient for a predetermined time span (e.g., 5 minutes). The master station **34** then returns to step **252** in order to process further location and/or use/status information.

[**0084**] Referring now to **FIG. 8**, there is provided an automated method **300** for gathering information about an activity or processes in a healthcare facility and analyzing the gathered information with a simulation modeling ("SM") tool such as a dynamic simulation modeling tool or a static simulation modeling tool. SM tools enable simulations of the relationships among various processes competing for space, time and resources and enable a quantitative assessment of the impact of proposed changes. However, such SM tools require an extensive amount of data associated with the activities and processes to be simulated and analyzed. Due to the costs associated with traditional methods for obtaining sufficient information regarding activities and processes, SM tools have not been utilized in the healthcare industry. The ABT system **10** greatly reduces the cost of information gathering thus making it feasible to apply SM tools and technology to the healthcare industry.

[**0085**] The automated method **300** of **FIG. 8** is illustrated and described in regards to gathering and analyzing information regarding the process of transferring a patient from one location to another location. However, those skilled in the art should readily appreciated that similar techniques apply to gathering and analyzing information about other processes.

[**0086**] In step **302**, the ABT system **10** receives information indicative of the start of the process to be recorded. For example, in the case of tracking a patient transfer, the ABT system **10** receives information describing a patient transfer order that has been entered into the ABT system **10** or a clinical information system in communication with the ABT system **10** in response to a written transfer order of a physician. In an alternative embodiment, the physician directly enters the patient transfer order into the ABT system **10** or the clinical information system in communication with the ABT system **10** via a point of care computer system.

[**0087**] The ABT system **10** begins to record information related to the monitored activity or process. In particular, the ABT system **10** in step **304** starts tracking the length of time to complete the patient transfer. For example, the ABT system **10** records the time at which the patient transfer order was received, records the time at which the patient transfer order was written by the physician, begins a timer in response to receiving the patient transfer order, and/or utilizes some other mechanism to track the length of time to complete the patient transfer.

[**0088**] The ABT system **10** also tracks and records the location and movement path of tagged objects associated

with the monitored activity. In particular, the ABT system **10** in step **306** monitors the location of the patient to be transferred based upon location information received from the badge **12** of the patient. Further, the ABT system **10** in step **306** continuously updates a graphical depiction of the current location of the patient upon one or more video displays **28**. The ABT system **10** causes one or more video displays **28** to provide further visual indications that a transfer is taking place such as (i) causing textual information indicative of the transfer to be displayed on video displays **28** (e.g., text in the scoreboard areas), and/or (ii) causing the graphical depiction of the patient and/or the room in which the patient is to be transferred from to be altered (e.g., blink, change color).

[**0089**] In step **308**, the ABT system **10** determines whether the patient has left the room based upon location information received from the badge **12** of the patient. If the ABT system **10** determines that the patient has not left the room, then the ABT system **10** returns to step **306** in order to further update the location of the patient. However, if the ABT system **10** determines that the patient has left the room, then the ABT system **10** in step **310** determines whether a caregiver is accompanying the patient based upon location information received by the badges **12** of the caregivers. If the ABT system **10** determines that a caregiver is not accompanying the patient, then the ABT system **10** returns to step **306** in order to further update the location of the patient.

[**0090**] The ABT system **10** in step **312** records which tagged objects (i.e., equipment, caregivers, etc.) are associated with the transfer of the patient. In particular, the ABT system **10** (i) determines based upon the location information received from badges **12** which caregivers are taking part in the transfer of the patient and which equipment is being transferred with the patient, and (ii) records identification information associated with such tagged objects. In an exemplary embodiment, the ABT system **10** determines which equipment is being transferred with the patient based upon information received from badges **12** of the equipment and business logic of the master station **34**. Alternatively, equipment may be manually associated with a patient via terminal (not shown) of the ABT system **10**, thus providing the ABT system **10** with an indication of which equipment needs to be tracked when the patient is transferred.

[**0091**] The ABT system **10** in step **314** tracks the length of time the identified tagged objects are involvement with the patient transfer. In particular, the ABT system **10** records the time at which each identified tagged object becomes involved with the patient transfer and records the time at which each identified tagged object becomes no longer involved with the patient transfer. Alternatively, the ABT system uses individual timers for each of the identified tagged objects or some other mechanism in order to track the objects involvement. In general, the ABT system **10** tracks the elapsed time of the patient from source (i.e., original room) to destination (i.e., new room), tracks the time of involvement of each of persons **14** involved with the transfer, and tracks the time of involvement for each piece of equipment involved with the transfer.

[**0092**] The ABT system **10** in step **316** records the movement of the patient, caregivers, and equipment associated with the patient transfer. The exemplary ABT system **10** periodically receives location information from the badges **12** of each tagged object on relatively short time intervals such as every 5 seconds. However, in order to reduce the amount of location information recorded, the ABT system **10** of the exemplary embodiment stores the location of each patient, caregiver, and equipment associated with the transfer on a longer time interval such as every 10 seconds. In an exemplary embodiment, the longer time interval used by ABT system **10** is user definable for each monitored activity in order to enable user selectable granularity of the movement path of the patient, caregivers, and equipment associated with a particular activity.

[**0093**] The ABT system **10** in step **318** determines based upon location information for the patient whether the patient has returned to the original room without being transferred to another room. If the ABT system **10** determines that the patient has been returned to the original room, then the ABT system **10** in step **320** stops monitoring the movement path and elapse times of the identified tagged objects and returns to step **306** without saving the acquired information. However, if the ABT system **10** determines that the patient has been transferred to another room, then the ABT system **10** in step **324** stores the acquired information (i.e., elapse times, movement, etc.) in a database.

[**0094**] The ABT system **10** then in step **326** utilizes SM tools to perform calculations on the information stored in the database. For example, the SM tools analyze the information to identify bottlenecks, resources consumed, critical paths, etc., related to transfers based upon information gathered over a predetermined time period. The ABT system **10** in step **328** updates information on the video displays **28** in order to indicate results of the SM tool analysis. For example, the ABT system **10** causes the video displays **28** to provide statistical information related to the monitored activity such as the number of transfers, the total cost of transfers, and personnel hours consumed due to transfers. Moreover, the ABT system **10** further causes the graphical depiction of rooms associated with awaiting transfers to blink, and causes the graphical depiction of hallways associated with bottlenecks in the physical transfer to blink red.

[**0095**] Referring now to **FIG. 9**, there is shown an exemplary graphical display **350** generated by the activity based tracking system **10** on video displays **28**. In the exemplary embodiment, the exemplary graphical display **350** is implemented as a MedModel application executing on the master station **34**. MedModel is a software tool of ProModel Corporation which is generally used for simulation modeling of healthcare facilities. The graphical display **350** includes a floor layout **352** and a scoreboard status **354**. The floor layout **352** depicts the physical features of the facility (i.e., location of walls, rooms, doorways, etc.) and the location of tagged objects (e.g., beds **16**, ventilators **18**, persons **14**). As indicated above, the master station **34** causes the floor layout **352** to provides visual indications of monitored activities (e.g., causes rooms, persons **14**, and/or equipment associated with a monitored activity to be highlighted, to be depicted in a different color, or to blink on and off.)

[**0096**] The scoreboard status **354** generally provides pseudo-realtime statistics and other information for the facility and activities monitored in the facility. For example, the master station **34** as a result of monitoring patient transfers displays the total number of patient transfers, the

total cost of patient transfers, personnel hours consumed due to patient transfers, and/or other statistical information associated with patient transfers over a certain time period.

[0097] While the invention has been illustrated and described in detail in the drawings and foregoing description, such illustration and description is to be considered as exemplary and not restrictive in character, it being understood that only exemplary embodiments have been shown and described and that all changes and modifications that come within the spirit of the invention and the attached claims are desired to be protected.

What is claimed is:

1. A system for tracking an activity in a healthcare environment, including:

a master station having a processor, a memory coupled to the processor, and a transceiver coupled to the processor;

a plurality of badges adapted for coupling to objects, each badge having a unique ID and including a transmitter for transmitting the badge ID; and

a plurality of sensors disposed throughout the environment, each sensor having a unique ID that relates the sensor to a location within the environment, and including a transceiver for receiving badge IDs from badges located near the sensor and transmitting the badge IDs and the sensor ID to the master station transceiver, the master station processor determining the location of an object from the received badge ID and sensor ID by identifying the badge associated with the object, relating the sensor ID to the location of the sensor, and storing object location information in the memory;

each of the badges further including a displacement sensor that generates signals indicating movement of the object coupled to the badge and a direction of the movement, the badge transceivers transmitting the signals for receipt by the sensor transceivers, the sensor transceivers forwarding displacement information representing the signals to the master station, the master station processor using the displacement information to update the stored object location information.

2. The system of claim 1 wherein the displacement sensor includes a speedometer.

3. The system of claim 1 wherein the master station updates the stored object location information of an object by computing a distance traveled and a direction traveled based on the signals from the displacement sensor associated with the object and modifying a last known location of the object by the distance and direction traveled by the object.

4. The system of claim 1 wherein the master station memory includes data representing physical characteristics of the environment.

5. The system of claim 1 wherein each badge transceiver transmits displacement samples at intervals that vary depending upon the rate of movement of the badge.

6. The system of claim 1 wherein the master station causes the plurality of sensors to transmit acknowledgement signals to badges that transmit object location information and displacement information, thereby providing the transmitting badges an indication that the object location information and displacement information was received by the master station.

7. The system of claim 1 wherein the master station transceiver is coupled to the sensors by a computer network.

8. The system of claim 1 further including a field generator for providing a reference field from which the displacement sensors generate the signals indicating the direction of the movement.

9. The system of claim 1 wherein the plurality of badges and the plurality of sensors include anti-collision circuitry to permit substantially simultaneous communications between multiple badges and a sensor.

10. The system of claim 1 wherein the sensors include short range sensors and long range sensors.

11. The system of claim 10 wherein the master station uses the object location information from the short range sensors to increase the accuracy of the object location information.

12. The system of claim 10 wherein the sensors include equipment sensors that provide status information associated with the equipment.

13. The system of claim 12 wherein the master station transceiver is coupled to the equipment sensors by a computer network.

14. The system of claim 12 wherein the master station transceiver includes a wireless transmitter and a wireless receiver for wirelessly communicating with the sensors and the equipment sensors.

15. The system of claim 12 wherein the status information includes an indication of whether the equipment is in use.

16. The system of claim 12 wherein the equipment sensors are associated with patients, the status information being time-stamped to permit correlation of patient billing to actual equipment usage.

17. The system of claim 1 wherein each displacement sensor includes an orientation sensor that provides signals indicating an orientation of the badge relative to a reference field.

18. The system of claim 17 wherein the orientation sensors include tilt correction circuitry.

19. The system of claim 1 further including displays coupled to the master station to receive object location information and provide a graphical display of the locations of objects within the environment.

20. The system of claim 19 wherein the displays are coupled to cameras located in the environment to provide video of objects, the displays being operable to display the video.

21. The system of claim 20 wherein the displays are portable.

22. The system of claim 1 wherein the master station determines a movement path and a location of an object associated with a badge based upon the received badge ID, the displacement samples, and a previously determined location of the badge.

23. The system of claim 22 wherein the master station compares the movement path to the data in the master station memory representing the physical characteristics of the environment to determine whether the movement path is consistent with available paths for movement of the object.

24. The system of claim 1 wherein the badge transmitters are RF transmitters that receive power from one of the plurality of sensors when in proximity of the sensor.

25. The system of claim 24 wherein the badges transmit the badge IDs in response to receipt of power from the sensor.

26. The system of claim 1 wherein each displacement sensor includes a motion sensor that generates a signal indicating movement of the object.

27. The system of claim 26 wherein the motion sensor signal indicates at least one of dynamic acceleration and static acceleration.

28. The system of claim 1 wherein each displacement sensor includes a direction sensor that generates a signal indicating a directional orientation of the object relative to a reference direction.

29. The system of claim 28 wherein the direction sensor signal indicates a horizontal orientation of the object relative to the reference direction.

30. The system of claim 28 wherein the direction sensor includes a three-dimensional field sensor and a pitch-and-roll sensor.

31. The system of claim 30 wherein the pitch-and-roll sensor includes a two-dimensional accelerometer.

32. The system of claim 1 wherein each of the badges includes a controller for processing the displacement sensor signals, and a memory for storing displacement samples representing the displacement sensor signals.

33. The system of claim 32 wherein the controller computes a speed of movement of the object.

34. The system of claim 32 wherein the plurality of badges transmit displacement samples at predetermined time intervals.

35. The system of claim 32 wherein the plurality of badges transmit badge IDs and any displacement samples stored in the badge memory since a prior receipt of an acknowledgement signal indicating a successful transmission of a prior displacement sample.

36. The system of claim 32 wherein the controller combines displacement samples that are temporally adjacent and do not significantly differ from one another, thereby reducing the number of displacement samples stored in the badge memory.

37. The system of claim 32 wherein the controller includes a counter for counting a number of displacement samples represented by a stored displacement sample.

38. The system of claim 32 wherein the badge controller includes a timer for time-stamping the displacement samples.

39. The system of claim 32 wherein each badge includes a battery for providing power to the badge in response to receipt of power from one of the plurality of sensors, the badge controller discontinuing battery power upon detection of a power off condition.

40. The system of claim 39 wherein the power off condition includes passage of a predetermined time period.

41. The system of claim 32 wherein the master station responds to receipt of a transmitted badge ID and a transmitted displacement sample by causing an acknowledgement signal to be sent to the badge.

42. The system of claim 41 wherein the acknowledgement signal is transmitted to the badge by a sensor transceiver.

43. The system of claim 42 wherein the controller responds to receipt of the acknowledgement signal by erasing the transmitted displacement sample from the badge memory.

44. A system for tracking an activity in a healthcare environment, including:

a first sensor associated with a person configured to transmit a first signal indicating the location of the person;

a second sensor associated with a piece of equipment configured to transmit a second signal indicating a condition of the equipment;

a plurality of first transceivers for receiving the first and second signals and transmitting information representing the first and second signals; and

a master station including a second transceiver in communication with the plurality of first transceivers for receiving the transmitted information to determine the location of the person and the condition of the equipment, the master station comparing the transmitted information to predetermined criteria and initiating an action when the transmitted information satisfies the predetermined criteria.

45. The system of claim 44 wherein the plurality of first transceivers include short range transceivers and long range transceivers.

46. The system of claim 44 wherein the second transceiver is coupled to the plurality of first transceivers by a computer network.

47. The system of claim 44 wherein the second transceiver includes a wireless transmitter and a wireless receiver for wirelessly communicating with the plurality of first transceivers.

48. The system of claim 44 wherein the master station causes the plurality of first transceivers to transmit acknowledgement signals to the first sensor, thereby providing the first sensor an indication that the transmitted information was received by the master station.

49. The system of claim 44 wherein the second sensor is one of a current sensor, a voltage sensor, and a power sensor.

50. The system of claim 44 further including a third sensor associated with the piece of equipment configured to transmit a third signal indicating the location of the equipment, the transmitted information from the plurality of first transceivers also representing the third signal from which the master station determines the location of the equipment.

51. The system of claim 44 wherein the action includes activation of a camera located in proximity to the person to obtain video of the person, the camera transmitting the video to a display for viewing by a caregiver.

52. The system of claim 44 further including displays coupled to the master station to receive person location information and provide a graphical display of a location of the person within the environment.

53. The system of claim 52 wherein the displays are coupled to cameras located in the environment to provide video of the person, the displays being operable to display the video.

54. The system of claim 52 wherein the displays are portable.

55. The system of claim 44 wherein the first sensor includes an RF transmitter that receives power from one of the plurality of first transceivers when in proximity of the first transceiver.

56. The system of claim 55 wherein the first sensor transmits the first signal in response to receipt of power from the first transceiver.

57. The system of claim 44 wherein the condition is whether the equipment is in use.

58. The system of claim 57 wherein the second sensor is associated with a patient, the second signal being time-stamped to permit correlation of patient billing to actual equipment usage.

59. The system of claim 44 wherein the person is a caregiver and the second sensor is associated with a handwashing device, the second signal indicating an in-use condition of the handwashing device.

60. The system of claim 59 wherein the predetermined criteria includes a hygiene policy, the action including generating a record of one of compliance and noncompliance with the hygiene policy.

61. The system of claim 44 wherein the first signal indicates the person's location relative to a side rail of a bed, and the second signal indicates an in-use condition of a ventilator.

62. The system of claim 61 wherein the predetermined criteria includes an extubation event wherein the person is contacting the side rail and the ventilator is in use, the action including notifying a caregiver of the extubation event.

63. The system of claim 44 wherein the master station confirms completion of the action upon receipt of an acknowledgment signal.

64. The system of claim 63 wherein a caregiver generates the acknowledgement signal by actuating a switch.

65. The system of claim 44 wherein the first signal indicates the person's position on a bed, and the second signal indicates a whether a side rail of the bed is in a lowered position.

66. The system of claim 65 wherein the predetermined criteria includes a potential fall condition wherein the person's position is one of near and moving toward the side rail and the side rail is in the lowered position, the action including notifying a caregiver of the potential fall condition.

67. The system of claim 66 wherein the action includes activation of a camera located in proximity to the person to obtain video of the person, the camera transmitting the video to a display for viewing by a caregiver.

68. A system for tracking activities in a healthcare environment, including:

a plurality of transmitters adapted to be coupled to a corresponding plurality of movable objects, each transmitter outputting a transmitter ID signal that identifies the corresponding object;

a plurality of sensors disposed at a corresponding plurality of locations throughout the healthcare environment, each sensor including a transceiver for receiving the transmitter ID signals and transmitting information including the received transmitter ID signals and a sensor ID signal indicating the location of the sensor; and

a master station in communication with the plurality of sensors, the master station including a receiver for receiving the information transmitted by the sensors, a processor for determining from the received information the location of each of the plurality of objects, a timer for monitoring the length of time objects remain in locations, and a memory for storing data indicating movement of the plurality of objects into and out of locations and the time such movement occurred;

wherein the master station automatically accumulates the data from the sensors, associates portions of the data with particular activities, and generates statistical analyses of the data associated with the particular activities to identify characteristics associated with the particular activities.

69. The system of claim 68 wherein the master station automatically detects an event associated with a beginning of a particular activity.

70. The system of claim 68 further including a display, the master station generating a graphical representation of the movement of the plurality of objects from the data in the memory for display on the display.

71. The system of claim 68 wherein the statistical analyses include information representing a number of objects involved in a particular activity, a time duration of involvement corresponding to each of the number of objects, and a cost associated with the particular activity.

72. The system of claim 68 wherein the sensors include short range sensors and long range sensors.

73. The system of claim 68 wherein the master station receiver is coupled to the plurality of sensor transceivers by a computer network.

74. The system of claim 68 wherein the master station receiver wirelessly receives the transmitted information.

75. The system of claim 68 wherein the plurality of transmitters and the plurality of sensors include anti-collision circuitry to permit substantially simultaneous communications between multiple transmitters and a sensor.

76. The system of claim 68 wherein each of the plurality of transmitters is an RF transmitter that receives power from one of the plurality of sensors when in proximity of the sensor.

77. The system of claim 76 wherein the plurality of transmitters transmit the transmitter ID signals in response to receipt of power from the sensor.

78. The system of claim 68 wherein each of the plurality of transmitters further includes a displacement sensor that generates signals indicating movement of the object coupled to the transmitter and a direction of the movement, the transmitter transmitting the signals for receipt by the plurality of sensor transceivers, the sensor transceivers forwarding displacement information representing the signals to the master station, the master station processor using the displacement information to update the data stored in the master station memory.

79. The system of claim 78 further including a field generator for providing a reference field from which the displacement sensors generate the signals indicating the direction of the movement.

80. The system of claim 78 wherein each displacement sensor includes an orientation sensor that provide signals indicating an orientation of the badge relative to a reference field.

81. The system of claim 78 wherein each displacement sensor includes a motion sensor that generates a signal indicating movement of the corresponding object.

82. The system of claim 78 wherein the displacement sensor includes a speedometer.

83. The system of claim 78 wherein the master station stores information representing the locations of the objects,

and updates the stored object location information of an object by computing a distance traveled and a direction traveled based on the signals from the displacement sensor associated with the object and modifying a last known location of the object by the distance and direction traveled by the object.

84. The system of claim 78 wherein each of the plurality of transmitters includes a controller for processing the displacement sensor signals, and a memory for storing displacement samples representing the displacement sensor signals.

85. The system of claim **84** wherein the controller computes a speed of movement of the object.

86. A system for tracking an activity in a healthcare environment, including:

means for collecting activity information including means for processing the information, means for storing the processed information, and means for transmitting and receiving signals;

a plurality of means respectively coupled to a plurality of objects for transmitting unique transmitter IDs respectively associated with the objects;

a plurality of means disposed throughout the environment for sensing transmissions from the plurality of transmitting means, each sensing means having a unique sensor ID that relates the sensing means to a location within the environment, and including means for receiving transmitter IDs from transmitting means located near the sensing means and transmitting the transmitter IDs and the sensor ID to the activity information collection means, the processing means determining the location of an object from the received transmitter ID and sensor ID by identifying the transmitting means associated with the object, relating the sensor ID to the location of the sensing means, and storing object location information in the storing means;

each of the transmitting means further including means for sensing displacement, the displacement sensing means generating signals indicating movement of the object coupled to the transmitting means and a direction of the movement, the transmitting means transmitting the signals for receipt by the sensing means, the sensing means forwarding displacement information representing the signals to the activity information collection means, the activity information collection means using the displacement information to update the stored object location information, and further including means for timing a length of time an object remain in a location, means for associating portions of the stored object location information with particular activities, and means for generating statistical analyses of the portions of stored object location information associated with the particular activities to identify inefficiencies associated with the particular activities.

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